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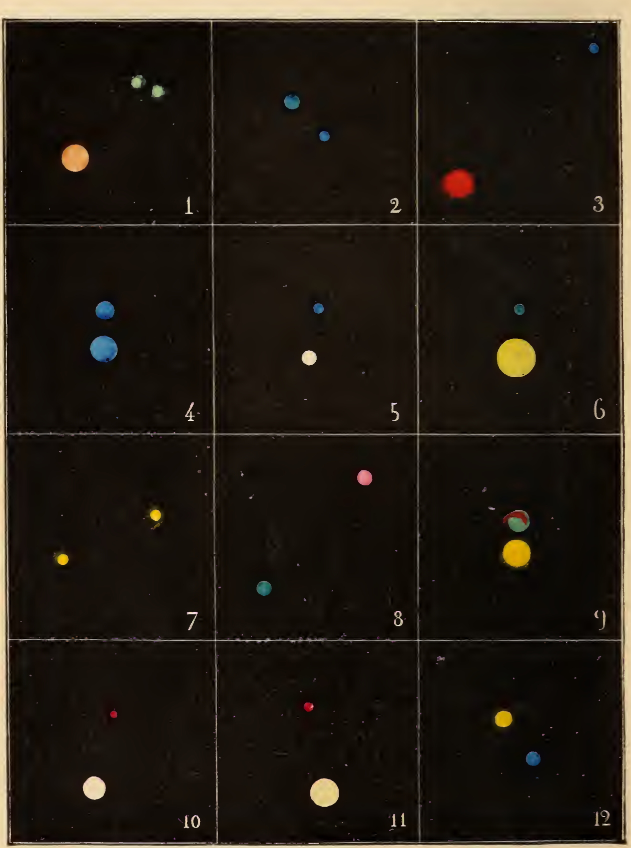
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THE

# MARVELS OF THE HEAVENS

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BY

CAMILLE FLAMMARION.

FROM THE FRENCH BY MRS. NORMAN LOCKYER.

With Forty-eight Illustrations.

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# BOOK I.

# I.

# NIGHT.

'O nuit! que ton langage est sublime pour moi,
Lorsque, seul et pensif, aussi calme que toi,
Contemplant les soleils dont ta robe est parée,
J'erre et médite en paix sous ton ombre sacrée!'
De Fontanes.

O Night, how sublime is thy language to me! . . . . Where are the souls to whom the spectacle of starry night is not an eloquent discourse? Where are those who have not been sometimes arrested in the presence of the bright worlds which hover over our heads, and who have not sought for the key of the great enigma of creation? The solitary hours of night are in truth the most beautiful of all our hours, those in which we have the faculty of placing ourselves in intimate communication with great and holy Nature. Far from spreading a veil over the universe, as is sometimes said, they only efface those which the sun produces in the atmosphere. The orb of day conceals from us the splendours of the firmament; it is during the night that the panoramas of the sky are open to us. 'At the hour of midnight, the heavenly vault is strewn with stars, like isles of light in the midst of an ocean extending over our heads. Who can contemplate them and bring back his looks to the earth without feeling sad regrets, and without longing for wings in order to take flight and be blended with them, or be lost amidst their immortal light?'

In the midst of darkness our eyes gaze freely on the sky, piercing the deep azure of the apparent vault, above which the stars shine. They traverse the white constellated regions, visiting distant regions of space, where the most brilliant stars lose their brightness by distance; they go beyond this unexplored expanse, and mount still higher, as far as those faint nebulæ whose diffused brightness seems to mark the limits of the visible. In this immense passage of sight thought with rapid wings accompanies the forerunning visual ray, carried away by its flight and wonderingly contemplating these distant splendours. The purity of the heavenly prospect awakens that eternal predisposition to melancholy which dwells in the depths of our souls, and soon the spectacle absorbs us in a vague and indefinable reverie. It is then that thousands of questions spring up in our minds, and that a thousand points of interrogation rise to our sight. The problem of creation is a great problem! The science of the stars is an immense science; its mission is to embrace the universality of created things! At the remembrance of these impressions, does it not appear that the man who does not feel any sentiment of admiration before the picture of the starry splendour, is not yet worthy of receiving on his brow the crown of intelligence?

Night is, in truth, the hour of solitude, in which the contemplative soul is regenerated in the universal peace. We become ourselves; we are separated from the factitious life of the world, and placed in the closest communion with nature and with truth. A poetess, Madame de Girardin, has described these impressions with an exquisite touch:—

'Voici l'heure où tombe le voile
Qui, le jour, cache mes ennuis :
Mon cœur à la première étoile
S'ouvre comme une fleur de nuit.

On nage, on plane dans l'espace,
Par l'esprit du soir emporté ;
On n'est plus qu'une ombre qui passe,
Une âme dans l'immensité.

D'un monde trompeur rien ne reste :
Ni chaîne, ni loi, ni douleur ;
Et l'âme, papillon céleste,
Sans crime peut choisir sa fleur.

O nuit ! pour moi brillante et sombre,
Je trouve tout dans ta beauté ;
Tu réunis l'étoile et l'ombre,
Le mystère et la vérité.'

Edward Young, he who, in Newton's language, gave us 'Night Thoughts,' was sometimes exalted to magnificent thought in his hymns :—

'O Majestic Night !
Nature's great ancestor ! Day's elder-born
And fated to survive the transient sun !
By mortals and immortals seen with awe !
A starry crown thy raven brow adorns ;
An azure zone, thy waist ; clouds in heaven's loom
Wrought through varieties of shape and shade,
In ample folds of drapery divine,
Thy flowing mantle form, and, heaven throughout,
Voluminously pour thy pompous train.
Thy gloomy grandeurs (Nature's most august,
Inspiring aspect !) claim a grateful verse ;
And like a sable curtain starr'd with gold,
Drawn o'er my labours pass'd, shall close the scene.

And what, O man ! so worthy to be sung ?
What more prepares us for the songs of heaven ?
Creation of archangels is the theme !
What to be sung so needful ? What so well
Celestial joys prepares us to sustain ?

* * * * *

Glance thy thought, and think of more than man.

* * * * *

This gorgeous apparatus, this display,
This ostentation of creative power,

This theatre,—what eye can take it in?
By what divine enchantment was it raised,
For minds of this first magnitude to launch
In endless speculation and adore?
One seen by day, by night ten thousand shine;
And light us deep into the DEITY!
How boundless in magnificence and might!
O what a confluence of ethereal fires,
From urns unnumber'd, down the steep of heaven,
Streams to a point, and centres in my sight!
Nor tarries there; I feel it at my heart.
My heart, at once, it humbles and exalts;
Lays it in dust and calls us to the skies.

* * * * *

O let me gaze! . . . .
O let me think! Thought too is wilder'd here;
In midway flight Imagination tires;
Yet soon reprunes her wing to soar anew,
Her point unable to forbear or gain;
So great the pleasure, so profound the plan!

* * * * *

Now go, Ambition! boast thy boundless might
In conquest o'er the tenth part of a grain.'

Of all the sciences, Astronomy is the one which can enlighten us best on our relative value, and make us understand the relation which connects the Earth with the rest of creation. Without it, as the history of past centuries testifies, it is impossible for us to know where we are or who we are, or to establish an instructive comparison between the place which we occupy in space and the whole of the universe: without it we should be both ignorant of the actual extent of our country, its nature, and the order to which it belongs. Enclosed in the dark meshes of ignorance, we cannot form the slightest idea of the general arrangement of the world; a thick fog covers the narrow horizon which contains us, and our mind remains incapable of soaring above the daily theatre of life, and of going beyond the narrow sphere traced by the limits of the action of our senses. On the other hand, when the torch of the Science of the Worlds enlightens us, the scene changes, the vapours which darkened the horizon fade away, our mistaken eyes contemplate in the serenity of a pure sky the immense work of the Creator. The Earth appears like a globe poised under our steps; thousands of similar globes are rocked in ether; the world enlarges in proportion as the power of our examination increases, and from that time universal creation developes itself before us in its reality, establishing both our rank and our relation with the numerous similar worlds which constitute the universe.

It is at night that this spectacle must be demanded—it is night which must be invoked in concert with the sacred bards whose lyre is worthy to sing its greatness:—

> 'O nuit! déroulez en silence
> Les pages du livre des cieux;
> Astres, gravitez en cadence
> Dans vos sentiers harmonieux;
> Durant ces heures solennelles,
> Aquilons, repliez vos ailes;
> Terre, assoupissez vos échos;
> Etend tes vagues sur les plages,
> O mer! et berce les images,
> Du Dieu qui t'a donné tes flots.'*

The silence and profound peace of a starry night present an appropriate scene to our contemplative faculty, and no time is more propitious to the elevation of the soul towards the beauties of the heavens. But the poetry of the sight of these appearances will be soon surpassed by the magnificence of the reality. And it is on this point that we must first insist, in order to get rid of all delusions caused by the senses. It seems to me right to remove the causes of error which may leave false impressions on our minds; it is completely useless, if not dangerous, to devote the first part of an astronomical discourse to describing apparent phenomena, which will afterwards have to be proved false. Let us not follow this troublesome road; let us keep away from the ordinary path, and begin, on the contrary, by raising the veil, in order to allow the reality to shine. Poetry, whose harmonious breath has just hushed our suspended souls, will not vanish on that account; it will rather regain a fresh aspect and new life, and, above all, a greater energy. Fiction can never be superior to truth; the latter is a source of inspiration to us, richer and more fruitful than the former.

---

* Lamartine.

## II.

## THE HEAVENS.

> 'Oh! depuis cette terre où rampent les mortels,
> De l'espace fuyant les vides éternels,
> Qui sondera des cieux l'insondable distance,
> Quand après l'infini, l'infini recommence!'

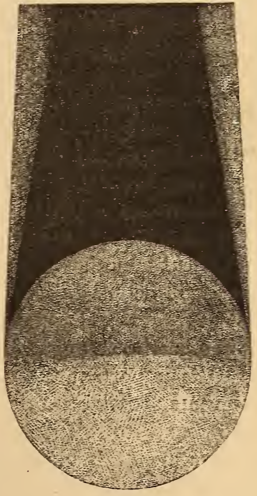

Fig. 1.—Night and Day.

The shade which spreads over the hemisphere in the absence of the Sun, from its setting to its rising, is only a partial phenomenon, circumscribed by the Earth, and in which the remainder of the universe does not participate. When we are enveloped in the calm silence of profound night, we are inclined to extend the scene which surrounds us to the entire universe, as if our world were the centre and pivot of creation. A few moments' reflection will suffice to prove how great this illusion is, and to prepare us for the conception of the whole world. It is, indeed, evident that the Sun cannot illuminate all sides of the same object at once, but only those which are turned towards it, only lighting up half the terrestrial globe at one time; hence it follows that night is nothing more than the state of the non-luminous part. If we imagine the terrestrial globe suspended in space, we shall understand that the side turned towards the Sun is alone illuminated, whilst the opposite hemisphere remains in shadow, and that this shadow presents the aspect of a cone. Moreover, as the Earth turns on itself, all its portions are presented successively to the Sun and pass successively into this shadow, and it is this which constitutes the succession of day and night in every country of the world. This simple *coup d'œil* suffices to show that the phenomenon to which we give the name of night belongs really to the Earth, and that the heavens and the rest of the universe are independent of it.

This is the reason why, if at any hour of the night we let our minds soar above the terrestrial surface, it will follow that, far from remaining always in the night, we shall again find the Sun pouring forth his floods of light through space. If we carry ourselves away as far as one of the planets which, like the Earth, revolves in the region of space where we are, we shall understand that the night of the Earth does not extend to those other worlds, and that the period which with us is consecrated to repose does not extend its influence there. When all beings are buried in the stillness of silent night here—above, the forces of nature continue the exercise of their brilliant functions—the Sun shines, life radiates, movement is not suspended, and the reign of light pursues its dominant action in the heavens (as on the opposite hemisphere to ours), at the same hour when sleep overcomes all beings on the hemisphere we inhabit.

It is important that we should know, first of all, how to habituate ourselves to this idea of the isolation of the Earth in space, and to believe that all the phenomena which we observe upon this globe are peculiar to it and foreign to the rest of the universe. Thousands and thousands of similar globes revolve like it in space. I do not now prove the truth of my assertions, but my readers will not doubt them, and will be willing to take my word, reminding me later to justify all that I shall have stated. Moreover, I promise them to do this as soon as possible; but I shall ask their permission to develope at once, in outline, a general idea of the universe.

One of the most fatal delusions which it is important we should get rid of at once, is that which presents the Earth as the lower half of the universe, and the heavens as its upper half. There is nothing in the world more false than this. The heavens and the Earth are not two separate creations, as we have had repeated to us thousands and thousands of times. They are only one. The Earth is in the heavens. The heavens are infinite space, indefinite expanse, a void without limits; no frontier circumscribes them, they have neither beginning nor end, neither top nor bottom, right nor left: there is an infinity of spaces which succeed each other in every direction. The Earth is a little material globe, placed in this space without support of any kind, like a bullet which sustains itself alone in the air, like the little captive balloons which rise and float in the atmosphere when the thin cord which retains them is cut. The Earth is a star in the heavens; it forms part of them; it [illegible] mpany with a great many other globes similar to it, p[illegible]s them; it is isolated in them; and all these other globes also float isolated in space. This conception of the universe is not only very important, but it is also a truth which it is absolutely necessary should be well fixed in the mind, otherwise three-quarters of the astronomical discoveries would remain incomprehensible. Here, then, is this first point well understood and thoroughly established in our thoughts. The heavens surround us on every side. In this space the Earth is a globe suspended; but the Earth is not alone in space. All those stars which sparkle in the heavens are isolated globes, suns shining by their own light; they are very distant from us; but there are stars nearer which resemble much more the one we inhabit, in the sense that they are not suns, but dark earths receiving, like ours, light from our Sun. These worlds called 'planets' are grouped in a family; ours is one member of this family. At the centre of this group shines our Sun, a source of light which illuminates it, and of heat which warms it. Floating in the bosom of the space which surrounds it on every side, this group is like a fleet of many boats rocked in the ocean of the heavens.

A multitude of suns, surrounded like ours with a family of which they are the foci and the light-givers, float likewise in all parts of the expanse. These suns are the stars with which the fields of heaven are scattered. In spite of the appearance caused by perspective, immense spaces separate all these systems from ours, spaces so great that the highest figures of our great numeration can scarcely number the smallest amongst them. A distance that our figures can scarcely express also separates these stars from each other, extending from depths unto depths.

Notwithstanding these prodigious intervals, these suns are in number so considerable that their numeration as yet exceeds all our means; millions joined to millions are inadequate to enumerate the multitude! . . . . Let the mind try if it is possible to repr[illegible]lf at one time this considerable number of systems a[illegible]e distances which separate them one from the other! Confused and soon humbled at the aspect of this infinite richness, it will only learn to admire in silence this indescribable wonder. Continually rising on the other side of the heavens, going beyond the distant shores of this ocean without limits, it will endlessly discover fresh new space, and new worlds will reveal themselves to our eagerness; heavens will succeed to heavens, spheres to spheres; after deserts of expanse will open other deserts, after immensities other immensities; and even when carried away without rest, during centuries, with the rapidity of thought, the soul would continue its flight beyond the most inaccessible limits that imagination could conceive,—there even the infinite of an unexplored expanse would remain still open before it; the infinite of space would oppose itself to the infinite of time; endlessly rivalling, without our ever being able to take away from the other: and the spirit will be arrested, overcome with fatigue, at the entrance of infinite creation, as if it had not advanced a single step in space.

Imagination suspends its flight and is stopped humbled.

> 'Ye stars! bright legions that, before all time,
> Camped on yon plain of sapphire, what shall tell
> Your burning myriads but the eye of Him
> Who bade through heaven your golden chariots wheel?
> Yet who, earth-born, can see your hosts, nor feel
> Immortal impulses — eternity?
> What wonder if the o'erwrought soul should reel
> With its own weight of thought, and the wild eye
> See fate within your tracks of deepest glory lie?'[*]

The immensity of the heavens has been sung on many lyres; but how can the song of man express such a reality? Poets have tried to render it in verse, when one feels the insufficiency of speech to note the immense thoughts which this wonderful contemplation develops in us.

Had I not reason for stating, as I did, that reality is superior to fiction, even from the point of view of poetical sentiments,— and that the contemplation of actual nature encloses a richer and more fruitful source of inspiration than the illusions of the spectacle offered by our senses? Instead of an immense night stretching itself to the azure vaults, instead of a robe worked with gold embroideries, or a veil covered with brilliant ornaments, we are in the bosom of life and universal brightness. Night is but an accident, a happy accident, which enables our looks to extend themselves beyond the limits which the day marks for us; we are like a traveller reclining in the shadow of a hill, who contemplates the illuminated landscape which is unfolded as far as the distant horizon. Instead of the immobility of dead silence, we are present at the spectacle of life on worlds. With the light of truth the arbitrary vaults disappear and heaven opens its depths to us; the infinite of creation is revealed with the infinite of space, and our Earth, losing the preponderance which our pretensions had accorded to it, gives way under our feet and disappears in the shade, losing itself in the midst of a multitude of similar little worlds. In the freedom of our flight we go beyond the solar regions and take our first sketch of the universe. It is thus that, disabusing ourselves of the first step of the ancient error too long established by appearances, we place ourselves in good condition for study, and prepare ourselves to receive easily the fresh truths which nature will reveal to us.

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[*] Croly, *The Stars.*

Allow me, in concluding this chapter, to relate an episode worthy of being more known than it has yet been, because it shows how much more power the real world has, than the empire of fiction. It is taken from the life of the great mathematician, Euler, and it was Arago himself who related it to the Chambre des Députés at the meeting of the 23rd of March, 1837.

'Euler, the great Euler, was very pious; one of his friends, a minister of one of the Berlin churches, came to him one day and said, "Religion is lost, faith has no longer any basis, the heart is no longer moved, even by the sight of the beauties,—the wonders of creation. Can you believe it? I have represented this creation as everything that is beautiful, poetical, and wonderful; I have quoted ancient philosophers and the Bible itself; half the audience did not listen to me, the other half went to sleep or left the church."

'"Make the experiments which Truth points out to you," replied Euler. "Instead of giving the description of the world from Greek philosophers or the Bible, take the astronomical world, unveil the world such as astronomical research has constituted it. In the sermon which has been so little attended to, you have probably, according to Anaxagoras, made the Sun equal to the Peloponnesus. Very well! say to your audience that, according to exact incontestable measurements, our Sun is 1,200,000 times larger than the Earth.

'" You have, doubtless, spoken of the fixed crystal heavens; say that they do not exist, that comets break through them; in your explanations planets were only distinguished from stars by movement; tell them they are worlds, that Jupiter is 1400 times larger than the Earth, and Saturn 900 times; describe the wonders of the ring; speak of the multiple moons of these distant worlds.

'" Arriving at the stars, their distances, do not state miles; the numbers will be too great, they will not appreciate them; take as a scale the velocity of light; say that it travels 186,000 miles per second; afterwards, add that there is no star whose light reaches us under three years; that there are some of them with respect to which no special means of observation has been used, and whose light does not reach us under thirty years.

'" On passing from certain results to those which have only great probability, show that, according to all appearance, certain stars could be visible several millions of years after having been destroyed; for the light which is emitted by them takes many millions of years to traverse the space which separates them from the Earth."

' Such was, gentlemen, shortened, and only with few modifications in figures, the counsel given by Euler. The advice was followed; instead of the world of fable, the minister presented the world of science. Euler waited for his friend with impatience. He arrived at last, with dull eye and in a manner which appeared to indicate despair. The geometer, very astonished, cried out, "What has happened?"

'" Ah! Monsieur Euler," replied the minister, "I am very unhappy; they have forgotten the respect which they owed to the sacred temple, they have applauded me." '

The scientific world was a hundred orbits greater than the world which the most ardent imaginations had dreamt of. There was a thousand times more poetry in the reality than in the fable.

# III.

## INFINITE SPACE.

> 'Insensé, je croyais embrasser d'un coup d'œil
> Ces déserts où Newton, sur l'aile du génie
> Planait, tenant en main le compas d'Uranie.
> Je voulais révéler quels sublimes accords
> Promènent dans l'éther tous les célestes corps;
> Mais devant eux s'abîme et s'éteint ma pensée.'
> ROUCHER.

THERE are truths before which human thought feels itself humiliated and perplexed, which it contemplates with fear, and without the power to face them, although it understands their existence and necessity: such are those of the infinity of space and eternity of duration. Impossible to define, for all definition could only darken the first idea which is in us, these truths command and rule us. To try and explain them would be a barren hope; it suffices to keep them before our attention in order that they may reveal to us, at every instant, the immensity of their value. A thousand definitions have been given, we will however neither quote nor recall one of them. But we wish to open space before us and employ ourselves there, in trying to penetrate its depth. The velocity of a cannon-ball from the mouth of the cannon makes swift way, 437 yards per second. But this would be still too slow for our journey through space, as our velocity would scarcely be 900 miles an hour. This is too little. In nature there are movements incomparably more rapid, for instance, the velocity of light. This velocity is 186,000 miles per second. This will do better; thus we will take this means of transport. Allow me then, by a figure of speech, to tell you that we will place ourselves on a ray of light and be carried away on its rapid course.

Taking the Earth as our starting-point, we will go in a straight line to any point of the heavens. We start. At the end of the first second, we have already traversed 186,000 miles; at the end of the second, 372,000. We continue. Ten seconds, a minute, ten minutes have elapsed,—111,600,000 miles have been passed. Passing, during an hour, a day, a week, without ever slackening our pace,—during whole months, and even a year, the time which we have traversed is already so long, that expressed in miles, the number of measurement exceeds our faculty of comprehension, and indicates nothing to our mind: they would be trillions, and millions of millions. But we will not interrupt our flight. Carried on without stopping by this same rapidity of 186,000 miles each second, let us penetrate the expanse in a straight line for whole years, fifty years, even a century . . . . Where are we? For a long time we have gone beyond the last starry regions which are seen from the Earth, the last that the telescope has visited; for a long time we travel in other regions, unknown and unexplored. No mind is capable of following the road passed over; thousands of millions joined to thousands ot millions express nothing: at the sight of this prodigious expanse the imagination is arrested, humbled. Well! this is the wonderful point of the problem: we have not advanced a single step in space. We are no nearer a limit than if we had remained in the same place; we should be able again to begin the same course starting from the point where we are, and add to our voyage a voyage of the same extent; we should be able to join centuries on centuries in the same itinerary, with the same velocity,—to continue the voyage without end and without rest; we should be able to guide ourselves in any part of space, left, right, forwards, backwards, above, below, in every direction; and when after centuries employed in this giddy course, we should stop ourselves fascinated, or in despair before the immensity eternally open, eternally renewed; we should again understand that our secular flights had not measured for us the smallest part of space, and that we were not more advanced than at our starting-point. In truth, it is the infinite which surrounds us, as we before expressed it, or the infinite number of worlds. We should be able to float for eternity without ever finding anything before us but an eternally open infinite.

Hence it follows, that all our ideas on space have but a purely relative value. When we say, for instance, to ascend to the sky, to descend under the earth, these expressions are false in themselves, for being situated in the bosom of the infinite, we can neither ascend nor descend; there is no above or below; these words have only an acceptation relative to the terrestrial surface on which we live.

The universe must, therefore, be represented as an expanse without limits, without shores, illimited, infinite, in the bosom of which float suns like that which lights us, and earths like that which poises under our steps. Neither dome, nor vaults, nor limits of any kind; void in every direction, and in this infinite void an immense quantity of worlds, which we will soon describe. It is this universal space that the author of the 'Génie de l'Homme' wished to celebrate, when he expressed the remarkable thoughts which follow:—

> 'Oui, quand je m'armerais des ailes de l'Aurore,
> Pour compter les soleils dont le ciel se décore;
> Quand de l'immensité sondant les profondeurs,
> Ma pensée unirait les nombres aux grandeurs;
> Sous ces gouffres sacrés égarant mon audace,
> Quand j'userais le temps à mesurer l'espace:
> Je verrais s'écouler les siècles réunis,
> Et pressé, sans espoir, entre deux infinis,
> Je me serais toujours écarté de moi-même,
> Sans jamais m'approcher de ce vaste problème.'

# IV.

## GENERAL ARRANGEMENT OF THE UNIVERSE.

### STARS ARE DISTRIBUTED IN CLUSTERS.

> 'On a sondé ces régions voilées
> Les bornes du possible ont été reculées !
> Un mortel a pu voir, armé d'un œil géant,
> Osciller des lueurs aux confins du néant.
> C'est vous dont notre Herschel, ô pâles nébuleuses
> Découvrit les clartés qu'on dirait fabuleuses !
> Il aperçut en vous des germes d'univers,
> Qui, selon leurs aspects et leurs âges divers,
> Ou contenaient encor leurs semences fécondes,
> Ou déjà répandaient leurs poussières de mondes !
> Eh bien ! de ces lueurs blanchâtres, que les yeux
> Discernent vaguement aux limites des cieux,
> L'une contient le ciel et le monde où nous sommes.
> Ah ! la terre est trop loin ! je ne vois plus les hommes.'
>
> J. J. Ampère.

In the bosom of infinite space, the unfathomable extent of which we have tried to comprehend, float rich clusters of stars, each separated by immense intervals. We shall soon show that all the stars are suns like ours, shining with their own light, and foci of as many systems of worlds. Now the stars are not scattered in all parts of space at hazard : they are grouped as the members of many families. If we compared the ocean of the heavens with the oceans of the Earth, we should say that the isles which sprinkle this ocean do not rise separately in all parts of the sea, but that they are united here and there in archipelagoes more or less rich. A Power as ancient as the existence of matter presided at the creation of these isles, each archipelago of which contains a great number; not one amongst them has risen spontaneously in an isolated region; they are all collected in tribes, most of which count their members by millions.

These rich groupings of stars have received the name of 'Nebulæ.' This name was given at the time of the invention of astronomical lenses, when these starry tribes were distinguished only under a diffused, cloudy aspect, which did not enable the eye to distinguish the composing stars. This appearance not revealing in any way the idea of solar clusters, it was thought that they were only phosphorescent, cosmical vapours, whirlwinds of luminous substance, or possibly primitive fluids, whose progressive condensation would in the future effect the formation of new stars. They were thought to assist at the creation of distant worlds, and sometimes, in remarking their different degrees of luminosity, people thought they could infer their relative ages, as in a forest the age of trees of the same species may be known on approach according to their size or the concentric circles which are formed each year under the bark. Thus the first nebula observed by the aid of the telescope and pointed out as an object of particular nature, the nebula of Andromeda, was considered for three centuries and a half as entirely deprived of stars. Simon Marius of Franconia, who from a musician became an astronomer—very compatible tastes, moreover—describing this oval and whitish appearance, which, more brilliant at the centre, became fainter at the edges, said that it resembled 'the light of a candle (*candela*) seen at a distance through a sheet of horn.' Only a few years ago a Cambridge astronomer counted within the limits of this nebula 1500 little stars, notwithstanding which, the centre still keeps the aspect of a diffused light, in spite of the best instruments. Later, the astronomer Halley thought no more of the star-clusters.

'In reality,' he states, 'these spots are nothing more than light coming from an immense space situated in the regions of ether, filled with a diffused and luminous medium by itself.' Others, again, imagined that at that spot the brightness of empyrean heaven was seen through an opening in the firmament. Derham said this, the author of astro-theology. But when optical instruments were perfected, this appearance of diffused light was transformed into a brilliant dotting; in proportion as the power of the telescope became more searching, the number of apparent nebulæ diminished, and at present many of those which in Galileo's time were regarded as cosmical clouds are resolved into stars. To be just, it must be added that in revealing the stellar composition of the first nebulæ, the telescope showed others whose nature has only quite recently been found out; these nebulæ remain in an indistinct state, not only on account of their prodigious distance, but because they are composed of vast cloud-masses of glowing gas.

Thus, infinite space must be represented as an immense void in the bosom of which are suspended archipelagoes of stars. These archipelagoes are themselves of infinite number, the stars which compose them can be counted by millions, and from one to the other the distance is incalculable. They are distributed in space in every direction, in every sense, following every imaginable course, and themselves invested with every possible form, as we shall soon see.

One of the most remarkable and regular nebulæ, and the one that may at the same time serve best for illustrating the arguments which precede, is the nebula in the Centaur. We shall study further on the aspect of the constellations and the most simple method of finding celestial objects most worthy of our attention. This nebula is presented under the following aspect in the field of a good telescope.

With the naked eye it is with difficulty distinguished as a point of faint light; in the telescope it is seen as a prodigious number of stars strongly condensed towards the centre. This condensation is a manifest proof that the cluster of stars is not only circular, but also spherical. One instant of attention suffices indeed to show that if we look at a sphere of stars at a distance, the visual ray will pass through less if it look at the edges of the sphere than if it look at the centre, and will meet with fewer stars on its passage towards the borders than towards the centre. In proportion as this visual ray gets nearer the centre its part comprised in the sphere will become longer, and the number of stars which it will meet goes on increasing. The maximum will be at the very centre. It was this optical effect which induced the belief in a condensation of nebulous matter. Halley discovered this cluster in 1679, whilst he was working at the catalogue of objects visible in the Southern heavens.

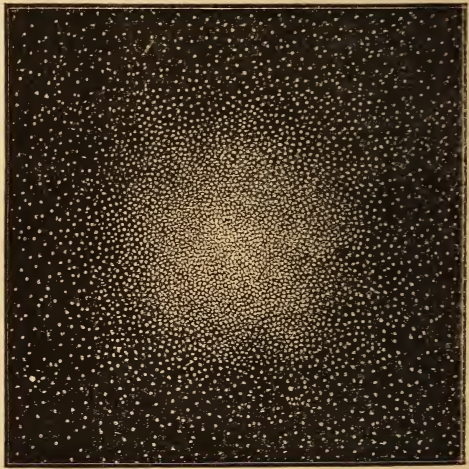

Fig. 2.—Cluster in the Centaur.

The limits of this cluster are not so clearly defined as in those which have particularly received the name of globular. Fig. 3 represents some types chosen from the latter.

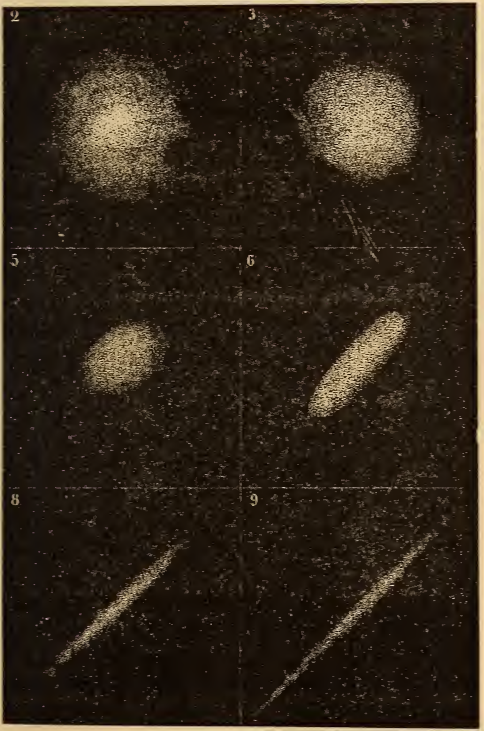

Fig. 3.—Globular Clusters.

Of these star-clusters the first are certainly spherical: others elongated, the thickness of which we see gradually diminished. These are probably also circular, but flattened in the form of lenses; instead of being presented to us in front they are seen edgeways.

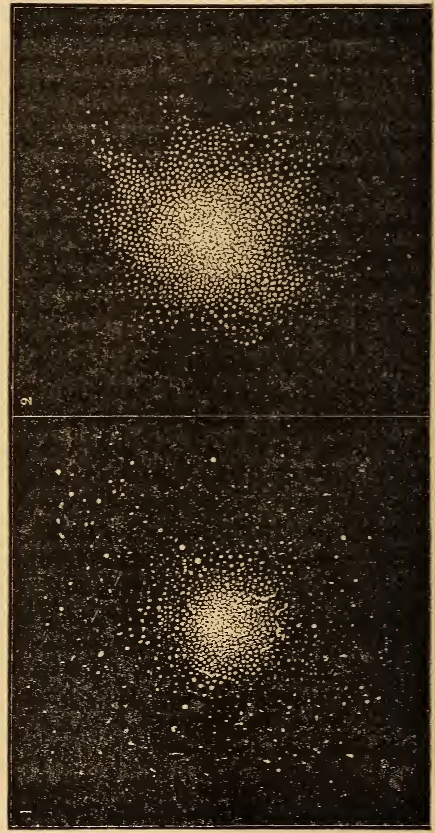

Fig 4.—Stellar Clusters.

At the sight of these globular masses one may ask with Arago, What is the number of stars contained in some of these clusters. The astronomer himself replied to his question. It would be impossible to count in detail and accurately the total number of stars of which certain globular nebulæ are composed; but one may be able to arrive at limits. In calculating the angular space of the stars situated near the edges, that is to say, in the region where they do not project on

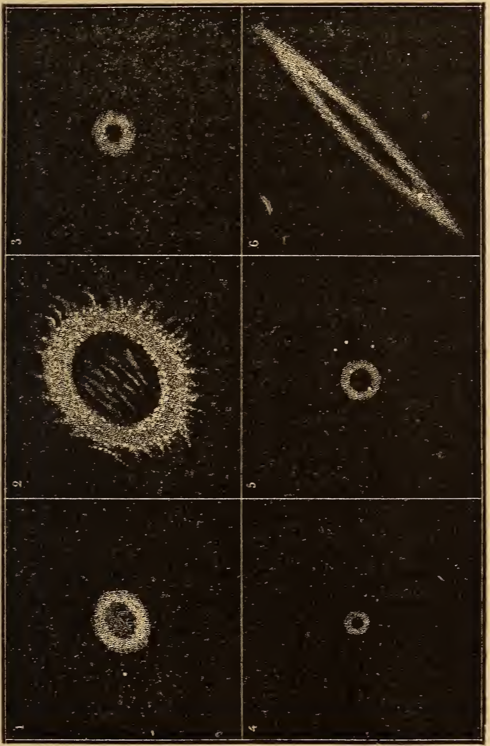

Fig. 5.—Annular Nebulæ.

each other, and comparing them with the total diameter of the group, it is certain that a nebula, whose apparent superficial extent is scarcely equal to the tenth of that of the lunar

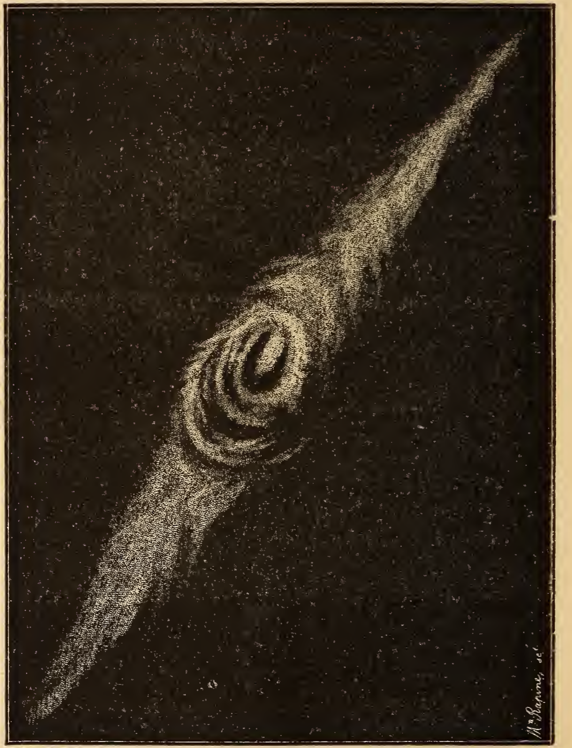

Fig. 6.—Nebula in the Lion.

disc, does not contain less than 20,000 stars; this is the minimum. The dynamic conditions proper to insure the indefinite preservation of a similar multitude of stars, does not seem easy to imagine, adds the celebrated astronomer. Supposing the system at rest, the stars in time will fall on each other. Giving it a rotatory movement round a single axis, shocks will inevitably take place. After all, is it certain *à priori* that the globular systems of stars must be preserved indefinitely in the state in which we now see them?

The examination of changes which have taken place in other systems led to the belief, on the contrary, that there is nothing infinitely stable there, and that movement governs these clusters of suns, as well as it governs each of the stars, and each of the little worlds which revolve round them.

The most regular nebulæ are not the most curious; notwithstanding, the aspect of some of them leaves a certain wonder in the mind. There are star-clusters which, instead of being condensed in an immense globe, are distributed in a crown, presenting the appearance of a circular or oval nebula, but hollow at its centre. Two types of this kind are represented in figs. 5 and 6.

The first is the perforated nebula of Lyra; the second is that of Andromeda. In the one, the magnificent telescope of Lord Rosse shows dazzling borders of stars close together, and luminous fringes notching the outer edge; in the other, two suns, symmetrically placed on one side and the other of the ellipse, appear destined to the government of this system in its passage through space. Perforated nebulæ, says A. de Humboldt, are one of the rarest curiosities. That of Lyra is the most celebrated; it was discovered in 1779, at Toulouse, by Arquier, at the time when the comet pointed out by Bode approached the region that it occupied. It is about the apparent size of the disc of Jupiter, and forms an ellipse, its two diameters being in the ratio of four to five. The interior of the ring is not dark, but slightly luminous. The hollow space is, however, of a very deep black in the beautiful perforated nebulæ of the Southern hemisphere. All are probably star-clusters in form of rings.

The interesting nebula sketched on the foregoing page will serve us as a transition between the regular and irregular nebulæ ; it is the elliptic annular cluster in the Lion. It appears to possess a central nucleus of great condensation. This nucleus is enveloped with concentric spheres, more or less filled with stars, separated from each other by spaces, and these envelopes succeed each other along a great axis, getting further from the centre, diminishing in extent equally on all sides, as far as the point where they fade away in a cone.

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## V.

## CLUSTERS AND NEBULÆ—(CONTINUED).

'When night, with wings of starry gloom,
O'ershadows all the earth and skies,
Like some dark, beauteous bird, whose plume
Is sparkling with unnumber'd eyes—
That sacred gloom, those fires divine,
So grand, so countless, Lord, are Thine!'
MOORE.

IN proportion as the magnifying power of telescopes is increased, the contour of these star-clusters, like their interior aspect, presents itself under a more and more irregular form. Such of these objects which formerly appeared purely circular or elliptical, have since showed great irregularity in their form as well as in the degree of their luminosity. In the place where pale and whitish clouds gave out a calm and uniform light, the giant eye of the telescope has discovered alternately dark and luminous regions. The figures we are about to give all tend to support this remark; others confirm it in a still more striking manner. For instance, there is in the zodiacal constellation of the Bull a uniform and oval nebula, which does not present the least singularity in instruments of small power; but when Lord Rosse pointed his telescope to it for the first time, he could not resist immediately giving it the singular name of the Crab nebula, which its form alone suggested. The ellipse was changed into a fish; the antennæ, claws, and tail were depicted on the black sky by a white outline, formed by long trains of stars.

There are irregular clusters and nebulæ of every possible shape, and of the thousands which have been already observed, described, and sketched, no two of them have been found to resemble each other. They take the most extraordinary forms. Some present the aspect of real comets; the nucleus is accompanied with a large tail and long luminous train:

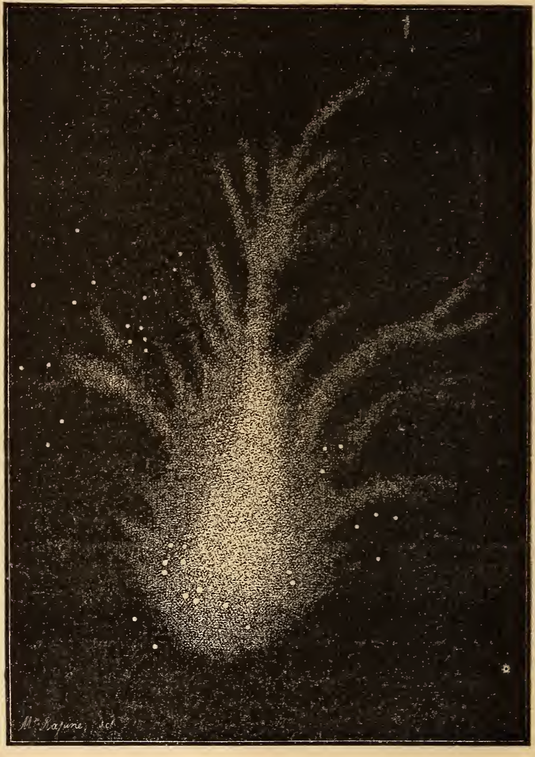
Mᵉ Rapine, sc.

Fig. 7.—Crab Cluster in the Bull.

these are in the Unicorn, the River Eridanus, and the Great Bear; and especially that in the Ship Argo, in which is again found the classical type of the most regular comets. Others, like that in Orion, most celebrated by the study which has distinguished it, or like that of the Magellanic Clouds and in the Ship ($\eta$), appear like immense vaporous clouds tossed about by some rough winds, pierced with deep rents and broken in jagged portions. Another, again (that in the Fox), resembles the dumb-bells which gymnasts lift up to exercise the power of the arms; that in Sobieski's Crown describes on the page of heaven the last capital of the Greek alphabet, Ω.

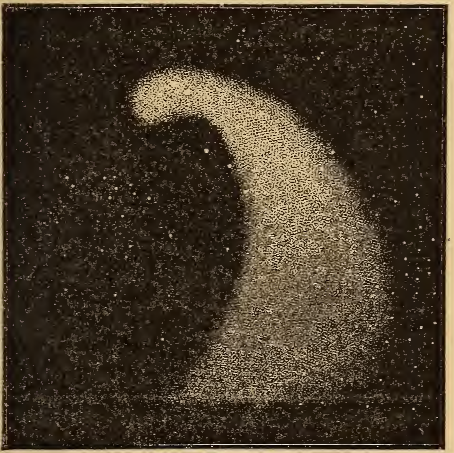

Fig. 8.—The Ship Argo

Other nebulæ are grouped together, as if two or three of these vast systems had united their destinies. Many are double; we see two spherical masses united by the diffused glow which envelopes them, or they may be separated by a slight angular distance, or sometimes even enclosed in luminous concentric strata like two eggs of snow in the midst of a nest of light. Again, elsewhere, in the Magellanic Clouds in the Southern hemisphere, we see four circular nebulæ arranged at the four angles of a lozenge, itself illuminated with fine star-dust; at one of the extreme angles, the nebula is itself divided into four globes, so that in reality we have before us an

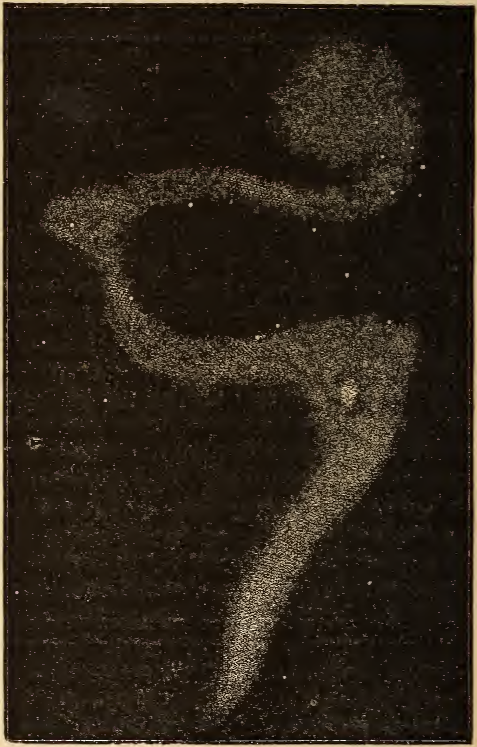

Fig. 9.—Sobieski's Crown.

immense cluster of stars, of which the extreme limits present seven principal condensations. But this is not all. Not only do these distant systems, some of them peopled with myriads

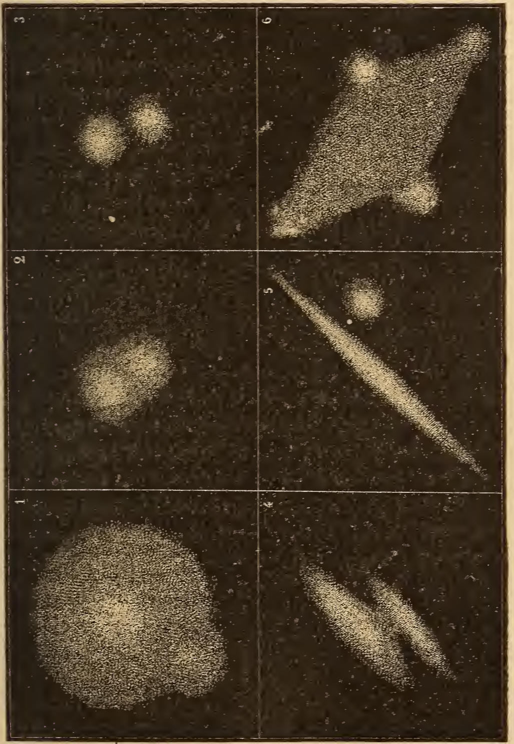

Fig. 10.—Double and Multiple Nebulæ.

of suns, take the most varied forms, not only do they present a diversity of aspect greater than it is possible to imagine; but some of them also unfold to the astonished eye which contemplates them varied shades and real colours. One is of a beautiful indigo blue; another is rose-coloured at its centre with a white border, another again emits magnificent sky-blue rays. This colouring is produced by the actual colour of the stars which compose it.* Others have been seen whose luminous intensity has perceptibly varied; the brightness of one of them has faded to such a degree as to be rendered completely invisible.

It is difficult to describe the impression which the sight of these distant universes makes on the mind when one sees them through the wonderful telescopes of modern times. The rays of light which reach us from so far place us for the time in communication with these strange creations, and the sentiment of terrestrial life hushed in the silence of night seems governed by the influence which celestial contemplation so easily exercises on the captivated soul. Earthly things lose their value, and one joins willingly with the voice of the poet of the Irish Melodies :—

'There's nothing bright but heaven,
And false the light on glory's plume,
As fading hues of even ;
And Love and Hope and Beauty's bloom,
Are blossoms gathered for the tomb ;
There's nothing bright but heaven.'

One feels that, in spite of the unfathomable distance which separates our abode from these far-off dwellings, there are there luminous foci and centres of movement: it is not a void, it is not a desert; it is 'something,' and this something suffices to attract our attention and awaken our reverie. An indefinable impression is communicated to us by the stellar rays which descend silently from unexplored abysses; one feels it without analysing it, and the traces of it remain ineffaceable, like those felt by a traveller when he steps on strange lands, and sees new skies above his head. This is described by the illus-

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* This remark applies to the clusters only. In the nebulæ the colours are due to another cause.—Tr.

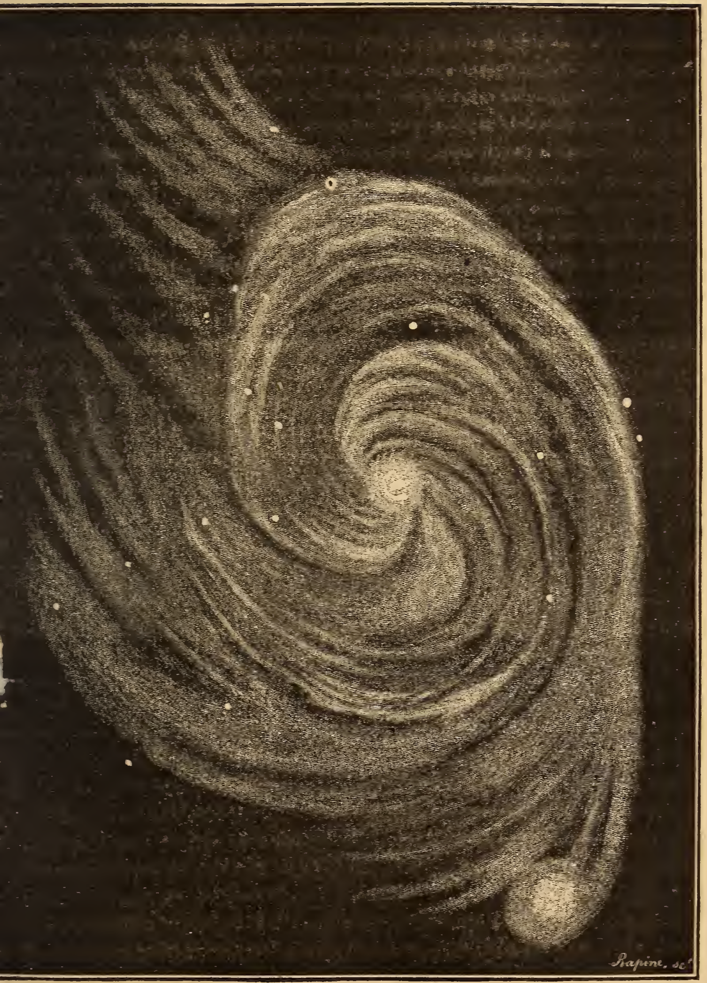

Fig. 11 —Spiral Nebula in the Constellation of the Hunting Dogs.

trious author of 'Cosmos,' when he presents the Magellanic Clouds, vast nebulæ close to the Southern pole, as a unique object in the world of celestial phenomena. 'The magnificent zones of the Southern heavens comprised between the parallels from fifty and eighty degrees, are the richest in nebulous stars and irreducible nebulous clusters. Of the two Magellanic Clouds which lie near the Southern pole, this pole so poor in stars that it might be called a waste country, the largest especially appears, according to recent researches, to be a wonderful agglomeration of spherical clusters of large and small stars, and irreducible nebulæ, whose general brightness lights up the field of sight and forms the background of the picture. The aspect of these Clouds, the brilliant constellation of the Ship Argo, the Milky Way, which extends between the Scorpion, Centaur and Cross, and the picturesque aspect of the whole Southern sky, have produced on my mind an ineffaceable impression.' Nevertheless, the most magnificent and eloquent aspect of the nebulæ has not yet been revealed to us by those which precede. To form an idea of the importance of these objects, and to appreciate their value, from the space which they occupy, also from the time which has been necessary for their formation, we must see the splendid spiral nebulæ which the powerful telescope at Parsonstown unveils to us, and which in ordinary instruments only present appearances similar to those we have already noticed.

Lord Rosse, indeed, was the first to discover that the vast systems of suns were clustered, not only simply round a centre of condensation, not only in masses more or less regular, but according to a distribution which reveals the existence of gigantic forces in action among them. He observed some immense agglomerations of which the composing stars were distributed in long lines in a general system of spiral curves.

From the principal centre springs a multitude of luminous spirals, formed of a numberless quantity of suns or nebulous masses, shaping the resplendent nucleus, whence they issue to be lost in the distance, imperceptibly parting with their brightness, and dying away as trains of phosphorescent vapours. A secondary nucleus brings up on one side the extremities of the longest spirals. There are splendid bands of constellated light, terminated with two rounded nodes. This rich spiral nebula belongs to the constellation of the Hunting Dogs. Before the discovery due to the powerful telescope which removed the veil with which it was enveloped, the best instruments only showed it as a single ring, one half of its contour surrounding a very bright globular nebula at its centre. Beyond the ring was noticed a second very small round nebula. Never was change of form more manifested between the aspects revealed by telescopes of different powers. To imagine the myriads of centuries necessary to the formation of these immense systems would be a vain undertaking. It is with slowness that nature accomplishes its most tremendous operations. In order that cosmical matter or the prodigious assemblage of so many stars could be distributed according to the curves revealed by the telescope, and winding round each other in gigantic spirals under the governing action of the combined attraction of all parts which compose this universe, it would require an incalculable series of accumulated years to pass away. Here especially it is truth to say that the luminous rays which descend from those distant creations are to us the most ancient testimony of the existence of matter.

The spiral nebula of the Hunting Dogs is not the only one of this form. In the constellation of the Virgin, Lion, and Pegasus, we also admire similar systems. That in the Virgin, situated in the central ring of this figure, is presented under the aspect of the 'wheels' that we see in fireworks; from the luminous centre white trains of light wind round, all guided and curved in the same direction; dark spaces separate them and give more clearness to the sketching of their direction. That in the Lion presents a series of oval concentric zones enveloping the centre, also more luminous; numerous stars shine out in the centre. The spiral nebula of Pegasus, marked with a beautiful star at its central point, is circular, and composed of circles alternately dark and luminous; on one side the circumference is cut by a tangent, a wide line of light longer than the nebula itself, to which this appears to

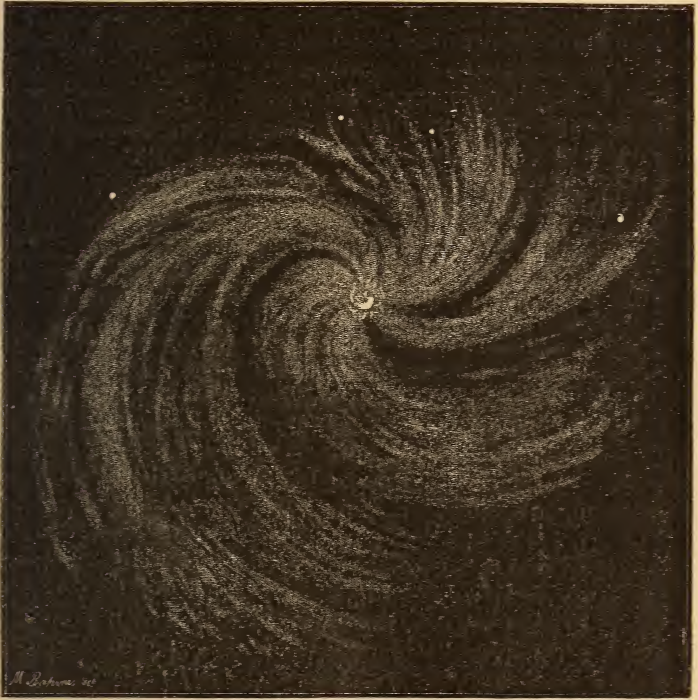

Fig. 12.—Spiral Nebula in the Virgin.

be attached, like the little silken nests of insects on branches. In writing these lines, I am reminded of the year 1702, in which a maker of systems wrote a large book proving that the universe is a large spiral. According to him, God was placed at the centre of the heavens; from this centre He would communicate with all other created beings by an infinity of spiral lines directed towards the circumference. Sun and worlds, bodies and spirits, all would move in a spiral. If this singular author were again born in our day, with what delight would he seize our spiral nebulæ to illustrate his thesis.

Nebulæ are not uniformly spread in all regions of the sky. On the starry sphere vast localities may be observed where no nebula is visible, whilst, in other parts, they appear really heaped up.

The richest region of the heavens is in the following group of constellations, which will soon be recognised: the Great Bear, Cassiopea, Berenice's Hair, the Virgin. In the zodiacal region, near the Virgin, in an hour may be seen more than three hundred nebulæ; whilst, in the opposite region, a hundred would not be met with. The spaces which precede or follow nebulæ contain few stars. Herschel found this rule constant—so constant, in fact, that each time during a certain period no star was brought in the field of his immovable telescope by the movement of the heavens. he used to say to his secretary who assisted him, 'Get ready to write, nebulæ are coming.'

From this fact, namely, that the spaces poorest in stars are near the richest nebulæ, and from the other, that stars are generally more condensed towards the centre of nebulæ, follows a confirmation of what we said before on the incessant work of many centuries which would be required to elaborate these systems. There is nothing astonishing that these powerful unions were formed, either at the expense of the surrounding cosmical matter, destined to be condensed in stars, or at the expense of the stars themselves, and that the spaces which surround them resemble vast deserts or regions laid waste.

At the sight of the pale nebulæ which sprinkle the expanse, the soul feels itself attracted, as at the edge of those abysses whose unknown depth produces giddiness. To the greatness of the spectacle succeeds a dearer sentiment, a sentiment of affection for these mysterious beauties, and one understands how much they exceed the most precious riches of earth.

'Ye stars! which are the poetry of heaven!
If in your bright leaves we would read the fate
Of men and empires,—'tis to be forgiven,
That, in our aspirations to be great,
Our destinies o'erleap their mortal state,
And claim a kindred with you; for ye are
A beauty and a mystery, and create
In us such love and reverence from afar,
That fortune, fame, power, life, have named themselves a star.

All heaven and earth are still—though not in sleep,
But breathless, as we grow when feeling most;
And silent, as we stand in thoughts too deep:
All heaven and earth are still. From the high host
Of stars, to the lulled lake and mountain-coast,
All is concentred in a life intense,
When not a beam, nor air, nor leaf is lost,
But hath a part of being, and a sense
Of that which is of all Creator and defence.

Then stirs the feeling infinite, so felt
In solitude, when we are least alone;
A truth, which through our being then doth melt,
And purifies from self; it is a tone,
The soul and source of music, which makes known
Eternal harmony, and sheds a charm
Like to the fabled Cytherea's zone,
Binding all things with beauty;—'twould disarm
The spectre Death, had he substantial power to harm.

Not vainly did the early Persian make
His altar the high places, and the peak
Of earth, o'ergazing mountains, and thus take

A fit and unwalled temple, there to seek
The Spirit, in whose honour shrines are weak,
Upreared of human hands. Come, and compare
Columns and idol-dwellings, Goth or Greek,
With nature's realms of worship, earth and air,
Nor fix on fond abodes to circumscribe thy prayer!'*

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* *Childe Harold.*

# VI.

## THE MILKY WAY.

O nuit majestueuse, arche immense et profonde,
Où l'on entrevoit Dieu comme le fond sous l'onde
Où tant d'astres en feux portant écrit son nom,
Vont de ce nom splendide éclairer l'horizon,
Et jusqu'aux infinis où leur courbe est lancée,
Porter ses yeux, sa main, son ombre et sa pensée !
Et vous vents palpitant la nuit sous ces hauts lieux,
Qui caressez la terre et parfumez les cieux !
Mystères de la nuit, que l'ange seul contemple,
Cette heure aussi pour moi lève un rideau du temple.
LAMARTINE, *Jocelyn.*

WE have seen that the universe is formed of clusters and nebulæ, spread in the immensity of space, at every imaginable depth and in every possible direction.* But then, if there are only nebulæ in space, and if no heavenly body is isolated from these clusters, our Earth, then, forms part of a nebula. The inhabitant of the terrestrial globe, then, finds himself also in the bosom of one of those immense clusters of stars which constitute the archipelagoes of the celestial ocean. And we do not, therefore, live, as appearances lead us to suppose, beyond this starry creation which shines over our heads. In a word, if all the celestial bodies are united in groups, the Earth, then, also belongs to a group of stars, and a cluster

Yes. The Earth, like all the stars, forms part of a cluster! It is not isolated in the deserts of the infinite; it is not an exception to the general law. The Earth, like the planets which are near it, belongs to the Sun. This Sun represents them in the universal numbering of the stars, for neither Earth nor planets count in the number of these splendours, and this Sun is one of the stars composing an immense nebula.

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* Let us now add that a recent discovery has proved several of the nebulæ to be composed of masses of incandescent gas.—TR.

The Sun is but a star! This assertion seems astonishing at first sight, on account of the illusions produced by the senses. The torch of our light, the focus of heat, the ruler of terrestrial life, appears to us under the legitimate prestige of its own power, and we bow to it as the prince of stars, as the first among the great ones of the heavens. And for us, indeed, it supremely deserves these titles, and all those which our just knowledge pleases to attribute to it. But if we consider it superior to the stars, if we find it more important, more magnificent, and more necessary, it is only because we are nearer to it, because in reality we are its tenants, its subjects, and that, contrary to that which happens on Earth, we recognise with delight the superiority of our master in the celestial realm. Belonging to him, we live at his expense, real parasites, and without him we should fall at once into the shades of death. To thank him and recognise his power is only just. Nevertheless, to judge things from an absolute point of view, we must rise above any particular dependence which may oppose the justice of our judgment, like him who, placed in the interior of an edifice and wishing to ascertain the rank of this edifice in the town, goes to a distance from it, and, placing himself on high ground, compares the various edifices with each other. We must, in the same way, put aside solar rule, and transport ourselves in spirit to a distant point in space, whence we should be able to determine the rank occupied by our Sun in the sidereal world.

Now, on getting further from the Sun towards any point in space, we shall see the Sun diminish in size and lose the importance which appeared to be his privilege. When we reach the limits of his system, he will then only present the aspect of a large star. On getting still further away, we shall see it descend to a simple star. Lastly, if we go towards any star in the heavens and continue to watch the decrease of the Sun which sinks behind us in the depths of space, it will become a small star soon lost in the multitude of others; the one we are approaching will lose, on the contrary, its small aspect, will increase, shine out, and get larger in proportion as we approach it, and will become a real sun, not less important than ours by its luminous and calorific power and by the gifts it distributes to the planets of its domain.

Passing beyond this new sun and continuing our path, we shall behold an analogous transformation of other stars into suns; all those towards which we shall pass successively will appear to us under this aspect, thus showing that they shine with their own light and are so many planetary foci. Lastly, when we shall have crossed these starry plains, we shall reach shores where the suns are more scarce, and soon, a desert void of stars.

To the thousand millions and thousand millions of miles we have just traversed, let us again add a certain quantity of thousands of millions, and we shall soon arrive at a favourable point for estimating the absolute rank of our Sun. Let us then suppose that we at last reach the point from which we see the suns constituting our cluster, and then returning by the way we came, we should find out what place our Sun occupies in the army of stars that we have left behind us.

It is there only that we can judge well of things. Now, this is what appears to us. All the stars which people our starry nights are enclosed in a narrow space, and we notice—now that we are beyond them—that they form a cluster of small bright points, and that they resemble an isle of lights suspended in space. In a word—and this is the point to which we wished to arrive—they form a cluster. This cluster is isolated; its limits are clearly enough defined, and no group, no star, shines in the space which surrounds it. It is marked out in the darkness in the following page (fig. 13).

This is the nebula in which we live; this is the abode of our solar world. In what part of it are *we?* The question is at least curious, and, from the spot, where we are placed to observe the star-cluster of which we form part under its true aspect, the best instruments would not succeed in distinguishing our little Sun. But it is not always necessary to see people in order to guess where they are. This is why we are able to travel towards the centre of the nebula, and, not far from the line which separates the zone into two layers, to observe a little point. This point is the place occupied by our Sun. The Earth and planets are with him; but, since it is impossible to distinguish the Sun in the midst of this multitude, *à fortiori*, the utter impossibility of perceiving the slightest vestige of the existence of our planetary system will be manifest.

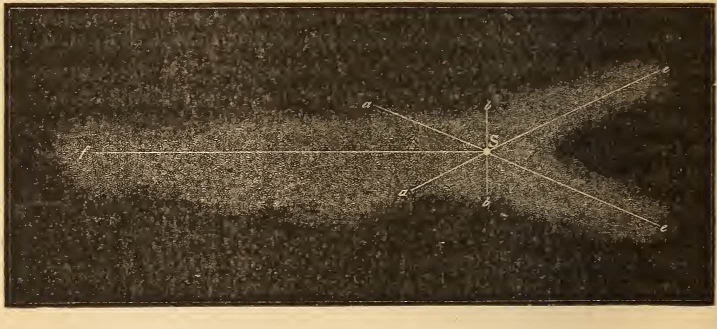

Fig. 13.—The Milky Way.

If we live thus in the middle region of a rich nebula, how is it, it may be asked by curious minds, how is it that we cannot distinguish it, and that our clear nights present around us a sky purely and splendidly starry? Is it then necessary to go away so many thousand millions of leagues from the Earth to know where it is placed? And if that is necessary, how has it been known?

No: this is not necessary, as the position is known. From the surface of our sphere we observe the sky, and we see that all around us a large nebulous circle envelopes our globe. We are ourselves near the centre of this circle, and each night displays over our heads a whitish band of dense stars continually surrounding us. This collection of stars, it has already been guessed, is the Milky Way.

The Milky Way, this wide irregular ribbon of stellar clouds which crosses the sky in all its width, is indeed nothing more than the greatest length of this immense lens of stars to which we belong. If the whole sky does not appear nebulous in every direction, it is precisely because the nebula to which we belong is not spherical, but of a lenticular form, and that in the thickness of the lens there is less depth and fewer stars than in the direction of the diameter. From the spot on which we are placed, if our sight pass through the greatest length it meets stars on stars indefinitely, because there is an immense expanse from the point where we are to the edges of the flattened nebula. But if our sight turn aside from the equatorial plane towards the sides, it meets with fewer stars as it gets further distant, and on reaching the polar diameter, scarcely any more will be met with. There are thirty times less stars in these regions than in those near the equatorial plane of the cluster.

All the stars which sparkle in the sky during a dark night belong to a single cluster, to a single nebula, the Milky Way marking its longitudinal direction. The stars are not isolated in an absolute manner, at random, in the deserts of space; they form part of a whole; the Sun which lights us is one of them; and they are counted by millions in a gigantic group, analogous to the distant clusters of which we have already spoken. Instead of only seeing a diffused glimmer, an indistinct light in the Milky Way, the telescope separates the stars which compose it and shows that it is formed of an innumerable multitude of stars very irregularly connected.

The idea which we must form of the Milky Way is then very different from that which appearances present to us and from that with which the ancients contented themselves. From the beginning of ages, from the first observations of an elementary astronomy, this semi-luminous train which crosses the sky was noticed, and the ruling mythology adorned it with images.

A Scotch poet of the sixteenth century, George Buchanan, described the history of the singular opinions entertained of the Milky Way; at the same time he rose above it to the true cause of this heavenly sight.

'Can I pass thee in silence? Thou whom ancient poets have celebrated so greatly in their songs! Thou who dividest the heavens with thy wide belt, and who formest one of its most beautiful ornaments! Thou shinest in the bosom of night, visible to the whole universe, attracting the eyes of mortals. Thou spreadest thy soft light each time that the cloudless atmosphere permits us to see the heavenly vault with clearness. That brilliant whiteness which causeth thee to be so easily noticed has given thee the name of the Milky Way, either (if fable has not imposed on the ancient poets) because some drops of milk fell from Juno's bosom and flowed among the stars, tracing on the azure of the heavens this belt remarkable for its whiteness, or, according to others, because it is the path which leads to the dwelling of the gods, and to the palace of the god of thunder. There are those who believe that it is the home which the shades of happy souls inhabit; that there, free from all work, free from all trouble, they live like gods in eternal bliss. Others persist that the pole still preserves the traces of the fire caused by Phaëton, when Phœbus' car, thrown from its path by this new conductor, left to the prey of the flames the heavenly abodes and omitted to embrace the universe. There are some who pretend that, when God created the world and gathered the different parts together, and united its immense sides, the ends of the heavens welding themselves together, left a seam between them, and formed a continual scar, which marks the point of union of all these parts. But those, who busy themselves with seeking the secret causes of heavenly phenomena, believe that this band is produced by a mass of contiguous little stars, whose united lights form this luminous whiteness, similar to that which twilight produces, or to that feeble light which the stars retain when they fade on the approach of Phœbus.'

These fantasies of imagination, authorised by old fables, were far from the truth; and in this case, as heretofore, truth is more beautiful, greater, and more admirable than fiction. From the day when the first astronomical glasses distinguished the stars whose cluster forms the glimmer of this zone, astronomers directed their attention to its constitution and structure. William Herschel, with the powerful telescope made with his own hands, resolved, towards the end of the last century, to count the stars comprised in this zone: he addressed himself to his task and divided his work into portions. His long perseverance was crowned with success. By a careful comparison of the parts where the condensation of stars attains its maximum with those where it attains its minimum, and by an examination of the extent occupied by these immense rings, the great observer found that the Milky Way did not enclose less than eighteen millions of stars!

Eighteen millions of stars in the equatorial stratum of the lenticular nebula to which we belong: this is not the total number of which it is composed, as this does not refer to the lateral portions of this gigantic mass, and all the stars of the heavens situated on one side and on the other of the plane of greatest condensation are not included in this enumeration. We shall see further on, in the chapter devoted to the study of the stars, that the total number of the members of this populous tribe is much greater still than eighteen millions. What is the real extent occupied by this collection of suns? The number of stars which compose it, and the relative distances from each other, comprises for this extent a number which the mind cannot well receive without being prepared for it, a number which it cannot appreciate without making great efforts to grapple it. I will not give the distance in leagues, because an immense continuation of leagues exceeds the limits of even the vision of the mind; it is better to take the measure used constantly for astronomical units. Now, the extent of the Milky Way, at its greatest length, would be measured by a ray of light which, travelling 186,000 miles per second, would travel in a straight line and without stopping for fifteen thousand years.

Thus, as we are ourselves near the centre of this nebula, when in the field of a powerful telescope we observe the little distant stars situated in the depths of the Milky Way, our retina receives the impression of a luminous ray, which started seven or eight thousand years ago from a sun analogous to ours and forming part of the same group.

If such be the extent of the nebula of which we are an infinitesimal constituent part, are not the other nebulæ scattered in space also as rich and vast; or rather is our nation privileged, and does it exceed the others in richness or in extent?

There is no reason to stop at this last idea, as a remnant of vanity would be perhaps able still to suggest to us, to make up a little for the mediocrity of the natural rank which we hold. The Milky Way is not unique; many of the nebulæ of the universe are so many Milky Ways, more or less similar to our own. Some may be less vast; others may possibly be vaster still, seeing that, in the domain of the infinite, space goes for nothing. It is best for us, then, to take the middle course, and to think that the pale and diffused nebulæ which seem to tremble in the distance in unfathomable immensities, are Milky Ways peopled with as many suns as our own. But then, as they appear so small to us, they must necessarily be distant from us. More distant, indeed, for if we find out at what distance we must remove our Milky Way in order to reduce it to the limit of a medium nebula, we find that we must remove it to 334 times its length, a distance which our agile messenger, a ray of light, takes a little more than five millions of years to accomplish. Such is the distance which may separate the gigantic clusters of suns, with which the sidereal universe is composed, and which hover in space, suspended at all depths of unfathomable immensity from each other. Contemplating these wonderful splendours we can understand that to poets they would be a subject of ecstasy, and we repeat with emotion the beautiful thoughts they have inspired:

'Oh, thou beautiful
And unimaginable ether! and
Ye multiplying masses of increased
And still-increasing lights! What are ye? What
Is this blue wilderness of interminable
Air, where ye roll along, as I have seen
The leaves along the limpid streams of Eden?
Is your course measured for ye? Or do ye
Sweep on in your unbounded revelry
Through an aërial universe of endless
Expansion—at which my soul aches to think—
Intoxicated with eternity?
Oh, God! oh, Gods! or whatsoe'er ye are!
How beautiful ye are! How beautiful
Your works, or accidents, or whatsoe'er
They may be! Let me die, as atoms die
(If that they die), or know ye in your might
And knowledge! My thoughts are not in this hour
Unworthy what I see, though my dust is;
Spirit! let me expire, or see them nearer.'*

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* Lord Byron, *Cain.*

# BOOK II.

# I.

## THE SIDEREAL WORLD.

'Un monde est assoupi sous la voûte des cieux,
Mais sous la voûte même où s'élèvent mes yeux,
Que de mondes nouveaux, que de soleils sans nombre
Trahis par leur splendeur étincellent dans l'ombre !
Les signes épuisés s'usent à les compter,
Et l'âme infatigable est lasse d'y monter !
. . . Là l'antique Orion, des nuits perçant les voiles,
Dont Job a le premier nommé les sept étoiles ;
Le Navire fendant l'éther silencieux,
Le Bouvier dont le char se traîne dans les cieux,
La Lyre aux cordes d'or, le Cygne aux blanches ailes,
Le Coursier qui du ciel tire des étincelles,
La Balance inclinant son bassin incertain,
Les blonds Cheveux livrés au souffle du matin,
Le Bélier, le Taureau, l'Aigle, le Sagittaire,
Tout ce que les pasteurs contemplaient sur la Terre,
Tout ce que les héros voilaient éterniser,
Tout ce que les amants ont pu diviniser,
Transporté dans le ciel par de touchants emblèmes,
N'a pu donner des noms à ces brillants systèmes.'
LAMARTINE.

According to what has been previously stated, we inhabit the midst of a vast nebula ; its equatorial stratum, projecting itself on our sky, describes that cloudy zone known under the name of the Milky Way. Our Sun is one of the stars composing this gigantic cluster, and all the stars which sparkle during our silent nights form part, like him, of this same tribe. This is, properly speaking, our universe. The other nebulæ may be considered by us as other universes, foreign to this one, and which we have only contemplated in order to give us a more distinct notion of the grandeur of creation, but which we will henceforth leave in the unexplored immensity which they inhabit in the midst of space. Descending from the great to the small, proceeding from the whole to a part, we will now embrace less vast proportions; we will pause at our sidereal universe, or, in other words, at the general description of the isles which constitute our celestial archipelago.

We will not yet speak of the nature of the stars, their distances, movements, or their particular history; before pursuing the reality, it will be well for us to make a digression on appearances. We are, however, averse to appearances, and much prefer reality; but there are some of which we cannot avoid speaking, seeing that they form in a certain way the surface of the things that must be searched into, and it is necessary to pass this surface before reaching the interior. But when we agree that such and such a phenomenon is only an appearance, there will be no harm in our studying it; the important points to be understood and to avoid confusion.

The stars appear scattered at random in the heavens. In a fine starry night, when our sight rises to these heights, a great diversity in their brightness is noticed, and at the same time an apparent disorder in their general arrangement. This irregularity and the number of the stars have prevented the possibility of giving to each of them a particular name; to recognise them and facilitate study, the heavenly sphere is divided into sections. The astronomy of the ancients, says Francœur, was confined to a few rough distinctions; they were at first contented to name the planets and most beautiful stars, and we have preserved this custom; but when they wished to study more carefully, and wished to describe stars of less brilliancy, they could only follow a method, the imperfection of which they acknowledged. They were led like the naturalists who, to name the species of the three kingdoms, unite under a common name a certain number of creatures which they afterwards distinguish from each other by a qualification. Astronomers have united the stars in different groups, on which they have drawn an animal or fabulous being. To these groups, or constellations, they gave names from fables, history, or the animal kingdom. These denominations, consecrated by antiquity, are quite arbitrary; and unless imagination itself creates images, as it sees pictures in the ever-changing contours of the clouds, we must not endeavour to find in the groups of stars anything which might recall the figure or imitate the image of the objects whose name the constellation bears. The necessity of being guided on the seas obliged man to choose in the heavens invariable signs by which he could direct his course, and this is the historical origin of the constellations.

The ancients formed representative maps of the heavens, and from the time of Hipparchus, the Greek astronomer, they were able to class the stars, distinguishing them according to their brightness, in the positions occupied by each of them on these figures.

It was necessary to fix on a method to find a particular star easily, in the midst of such a great number (four to five thousand) as is distinguished with the naked eye. The first origin of the constellations is unknown; but it is imagined that they were established successively. The Centaur Chiron, Jason's preceptor, has the reputation of having first divided the heavens on the sphere of the Argonauts; but Job lived before the time, when the precedent is placed, and this prophet then spoke of Orion, the Pleiades, and Hyades, three thousand three hundred years ago. Homer also speaks of these constellations when describing Vulcan's shield:—

> 'And on its surface many a rare design
> Of curious art his practised skill had wrought,
> Thereon were figured earth, and sky, and sea,
> The ever-circling sun, and full-orb'd moon,
> And all the signs that crown the vault of heav'n;
> Pleiads and Hyads, and Orion's might,

> And Arctos, call'd the Wain, who wheels on high
> His circling course, and on Orion waits;
> Sole star that never bathes in th' ocean wave.'*

The same mythological divisions are used in the present day. Since the establishment of Christianity, there have been many efforts to reform this pagan system, and to replace it by Christian denominations. In the planisphere of Bede, St. Peter is substituted for the Ram, St. Andrew for the Bull, &c. From these attempts, no name escapes; David's chariot, Solomon's seal, the three Magi kings, or Jacob's rod, &c., date the highest. Later still a German proposed to give to the twelve signs of the Zodiac the heraldry of the twelve most illustrious houses of Europe. These singular efforts remained sterile, and the mythological reign has continued until the present day.

As great diversity has been noticed in the brightness of stars, in order to facilitate their indication, they have been classed in order of magnitude. This word 'magnitude' is improper, seeing that it has no relation to the dimensions of the stars, these dimensions being still unknown to us; it dates from a period when it was believed that the brightest stars were the largest, and this is the origin of the denomination; but it is important to know that this is not its real sense. It simply corresponds to the apparent brightness of the stars. Thus, stars of the first magnitude are those which shine with the greatest brightness in dark nights; those of the second magnitude shine less, &c. Now, this apparent brightness belongs both to the real size of the star, its intrinsic light, and its distance from the Earth; consequently, it only possesses an essentially relative meaning. Nevertheless, it may be said generally that the brightest stars are nearest, that those whose pale glimmer is scarcely distinguished in the field of the telescope are more distant.

Thus, when we shall speak of the magnitude of stars, it is to be understood that we refer simply to their apparent brightness; this brightness greatly facilitates the means of distinguishing them among the constellations. There is now another fact which is not less important to consider as relative, and not as absolute; this is the arrangement of the stars or forms of the constellations. We know, already, that the sky is not a concave sphere in which bright nails are fastened, and that there is no kind of vault—only immense, infinite void surrounding the Earth on all parts and in every direction. We know, also, that the stars, suns in space, are scattered at every distance in the vast immensity. When, then, we notice two stars close together in the sky, their apparent proximity does not in any way prove their real proximity: they may be very distant from each other, in the direction of vision, at a distance equal to or greater than that which separates us from the nearest one. In a similar way, when four, or five, or more stars are united in the same group, this does not imply that these stars, forming the same constellation, are on the same plane and at an equal distance from the Earth. By no means. Dispersed at all depths of space, all around the terrestrial atom, the arrangement which they display to our eyes is only an appearance caused by the position of the Earth with regard to them. This is purely a matter of perspective. When we find ourselves during the night in the midst of a large, open space (for instance, the Place de la Concorde) in which numerous gas-lights are dispersed, it is difficult for us to distinguish, at a certain distance, the most remote lights from those which are less so: they all appear to be projected on the dark ground; moreover, their general arrangement depends purely on our point of view, and varies according as we ourselves walk away or across. This simple comparison may make us understand why the stars, lights in the dark space, do not reveal to us the distances which may really separate them, and why their arrangement on the apparent vault of the sky depends only on the spot where we place ourselves to examine them. On quitting the Earth's surface and transporting ourselves to a spot sufficiently distant, we should witness, in the apparent arrangement of the stars, a variation as much greater as our station of observation would be more distant from our previous one. For this it would be necessary to transport ourselves, not only to the last planets of our system, but beyond this system entirely, and to go to distances at least equal to those of the nearest stars. Indeed, from Neptune, the last planet of our system, the stars are seen in the same arrangement as from here. The change is only seen in quitting one star for another. One moment's reflection suffices to convince us of this fact, and to relieve us from further explanation on the subject.

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* Homer's *Iliad.*

These illusions once appreciated at their right value, we may, without fear, begin the description of the figures with which old fables have constellated the spheres. The knowledge of the constellations is necessary for the observation of the heavens and for researches which love of science or curiosity may inspire; without it, one finds oneself in an unknown country without any geography or possibility of discovering our whereabouts. Let us, then, form the geography of the heavens. The innumerable figures of animals, men, or objects, with which the sphere is adorned, will not, however, be drawn here, seeing that they would only serve to confuse the mind with imaginary lines. Formerly they printed celestial atlases, where the figures were represented with exquisite care, so much so, indeed, that they ended by forgetting the stars, and the sky was nothing more than a menagerie. In spite of the interest of the images, I will not follow this example. I will only give further on, on a special map, the drawing of the constellations visible in our hemisphere. At present, let us see how to direct our course for reading correctly the great book of the heavens.

There is one constellation known to every one; for greater simplicity we will begin with it, as it will serve us as a starting-point to go towards the others, and as a sign to find its companions. This constellation is the Great Bear, which has also been called David's Chariot, or Charles's Wain; which the ancients called *Septem triones* (whence came the word *septentrion*), or, again, *Helix, Plaustrum;* which the Greeks addressed under the name of Ἄρκτος μεγάλη, ἑλικὴ, &c., which the Arabs called *Aldebb al Akbar*, and the Chinese, three thousand years ago, addressed as the *Tcheou-pey*, the god of the north. Thus it can boast of a high celebrity. If, however, in spite of its universal notoriety, some have not yet had occasion to make its acquaintance, the following is the sign by which it may always be recognised. Turn towards the north, that is to say, opposite the spot where the Sun is at noon. Whatever may be the season of the year, the day of the month, or hour of the night, you will always see there a large constellation formed of seven stars, four of which are quadrilateral, and at an angle with the side; the whole arranged like this:

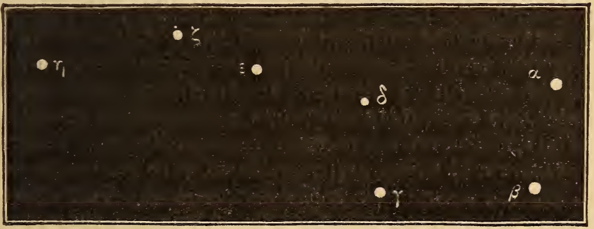

Fig. 14.—Constellation of the Great Bear.

Have you not all seen it? It never sets. Night and day it watches above the northern horizon, turning slowly in four-and-twenty hours around a star of which we shall speak presently. In the figure of the Great Bear, the three stars of the extremity form the tail, and the quadrilateral forms the body. In the Chariot the four stars form the wheels, and the three the car. Above the second between these latter, good sights distinguish a very small star called Alcor, which is also called the Cavalier. The Arabs called it Saidak, which means the proof, because they used it to test a good eye. Greek letters are used to denote each star; they are the first of the alphabet; α and β mark the two first stars, γ and δ the two others, ε, ζ, η, the three of the car; Arab names have also been given to them, but I shall pass over them in silence, as they are not generally used.

This brilliant septentrional constellation, composed (with the exception of δ*) of stars of the second magnitude, has received from olden times the gift of captivating the attention of observers, and personating the stars of the north. Many poets have sung its praises; we will only repeat in prose one,—the words being worthy of the majesty of the heavens,—that of Ware, the American poet,—

> 'With what grand and majestic steps this northern constellation advances in its eternal circle, following its royal path amidst the stars with a slow and silent light! Mighty creation, I worship thee! I love to see thee wandering in the brilliant avenues like a splendid giant with a strong belt,—severe, indefatigable, and resolute, whose feet never pause on their road. Other kingdoms abandon their nocturnal path and rest their wearied orbs under the waves; but thou, thou never closest thy fiery eye, and never stoppest thy determined step. Forward, always forward! whilst systems change, suns set, worlds slee and awaken, thou followest thy endless way. The adjacen horizon endeavours to arrest thee, but in vain. A vigilant sentinel, thou never quittest thy secular path, but, without allowing thyself to be overtaken by sleep, thou preservest the fixed lights of the universe, always preventing the north from forgetting its place. . . . . .
>
> 'Seven stars people this bright kingdom; the sight embraces the whole; their respective distances are not inferior to

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* This star is variable. Two hundred years ago it was not less brilliant than its companions.

their distance from the Earth. And here again we see the tremendous distance between the celestial orbs. From the depths of the heavens, unexplored by the mind, the piercing rays dart through space, revealing to the senses numberless systems and worlds. Our sight must arm itself with the telescope, and explore the heavens. The heavens are opened, a rain of sparkling fire falls on our heads, stars appear close together, are condensed in such far-off regions, that their rapid rays (more rapid than any other thing) have travelled for centuries in order to reach the Earth. Earth, Sun, and nearest constellations, what are you amidst this infinite immensity and the multitude of divine infinite works?'

These thoughts, inspired by scientific truth, are superior to those of ancient mythology. Without speaking of the name of Bear given to this constellation and the following one, not only by the Greeks and Latins, but again by other people who did not appear to have had any communication with them, like the Iroquois who gave to them the same name,* we shall state that, generally, the Great and Little

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* It is a remarkable fact, and one which may be used in the history of ancient astronomy in particular, as in that of the origin of people in general, that groups of stars without any characteristic figure have been called by the same name by the most diverse people. The Indians and Chinese have the same zodiacal constellations as the Greeks, bearing the same etymological names, and distributed in the same direction. The northern constellations have received the name of Bears with the people of High Asia, Phœnicians, Arabs, Greeks, and Iroquois, although the square and the tail drawn by their arrangement do not recall in any way the bears which have no tails. In America the name of the 'Jawbone of an Ox' is applied to the Hyades placed in the head of the Bull. With the Arabs, the constellation of Andromeda is a chained woman; with the Persians, Cassiopea is on a chair, and Hercules kneeling; the seven stars which we name the Pleiades, the Indians called Chickens; in India and Persia, Perseus bears a head: the Brahmins have sensibly the same zodiac as we have; the Milky Way of the Greeks is with the Chinese the Celestial River, to the Copts the Stubble field, to the savages of North America the Path of Souls, and to the inhabitants of the French provinces the Path of St. John. Beside the rare connexion which would strictly explain these designations, these coincidences remain the objects of great mystery. They would be in favour of the unity of a primitive human stock.

Bear were considered as Callisto and her dog. Jupiter had a son by this nymph, the cow-herd (Boötes), of whom we shall speak further on; he had them both placed in the sky. But the official wife of the king of gods, Madame Juno, as Virgil has said, was greatly incensed, and obtained from Thetis, the ruler of the waves, that these perfidious constellations should never bathe in the ocean. Thus their continued presence above the horizon is explained. Callisto, whose car fears the wave of Thetis, near the ice of the north shines out near her son. The Dragon embraces them like an immense wave. According to others, the two Bears are nymphs who fed Jupiter on Mount Ida; according to others, again, they represented the oxen of Icarus; but these fabulous fancies do not interest us more than they ought to do, and now that we recognise the Great Bear we must make him useful in our celestial voyages among the stars in his neighbourhood and our uranographic researches generally.

Let us return to the figure before traced. If a straight line be carried through the two stars, marked $\alpha$ and $\beta$, which form the extremity of the square, and prolonged beyond $\alpha$ to an extent equal to five times the distance from $\beta$ to $\alpha$, or, in other words, to an extent equal to the distance of $\alpha$ to the extremity of the tail $\eta$, a star less brilliant than the preceding ones is found, which forms the extremity of a figure like the Great Bear, but smaller and directed in a contrary direction. This is the Little Bear, or Little Chariot, also formed of seven stars. The star to which our line brings us, that which is at the extremity of the Bear's tail, or at the end of the shaft of the Chariot is the Pole Star.

The Pole Star has a certain renown, like all personages who distinguish themselves from others, because, among all the stars which twinkle in our starry nights, it remains immovable in the heavens. At any moment of the year, day or night, if you observe the sky you will always find it occupying the same place. All the other stars, on the contrary, revolve round it every twenty-four hours, a hold for the centre of this immense whirlpool! The Pole-Star remains immovable over one pole of the world, whence it is used as a fixed point by navigators of the pathless ocean, as well as by travellers in an unexplored desert.

Of the thousand facts which I could quote to show how many times the Pole-Star and its constellation, always visible in the north, have saved the lives of travellers lost in darkness, I shall content myself with the following, in which Albert Montemont honours the star of the north.

On the 4th of April, 1799, the English General. Baird, then at war against Tippoo-Saïb, received orders to march in the night, to observe a height on which it was supposed the enemy had placed an advanced post; Captain Lambton accompanied him as aide-de-camp. After having crossed this height several times, without meeting with any one, the General resolved to return to the camp, and he turned back, as it appeared to him, to the general quarters. But, as the night was light and the constellation of the Great Bear was near the meridian, Captain Lambton remarked, that, instead of returning south, as he must do to return to the camp, the division had advanced to the north, that is to say, towards the body of the enemy's army; and he instantly made the General aware of this mistake. But this officer, who troubled himself very little about astronomy, replied that he knew

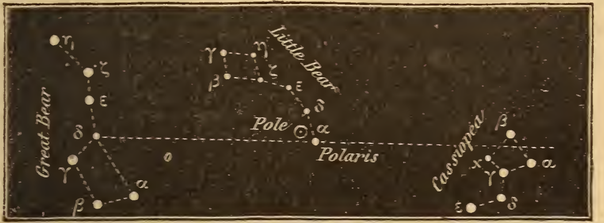

Fig. 15. Great Bear, Little Bear, Pole Star.

well enough what he was doing without consulting the stars. At the same instant, the detachments fell in with the enemy's advanced post. This surprise having confirmed the Captain's observation too well, they at first hastened to disperse the soldiers of the advanced post and then to turn back on their road. They procured a light, consulted a compass, and found, as the astronomical officer said laughingly, that the stars were right.

The immobility of the Polar Star at the north, and the movement of the entire heavens round it, are appearances caused by the movement of the Earth on its axis. We will give the evidence further on ; but, while we are visiting the country of the stars, we must not leave such a beautiful sight to descend to the Earth. Let us then continue our mode of surveying, and make ample acquaintance with the population of the starry heavens.

## II.

## THE NORTHERN CONSTELLATIONS.

> ‘Aux lieux où rayonnent des clartés éternelles
> Les cieux sont toujours purs et les nuits toujours belles,
> Où l’Euphrate roulant ses flots au loin couverts
> De l’ombrage fleuri de palmiers toujours verts,
> Voit de feux plus puissants la nature animée
> Prodiguer le cinname et la myrrhe embaumée,
> Le pasteur de Babel en gardant ses troupeaux
> Observa le premier les célestes flambeaux;
> Et, la nuit, promenant ses tentes égarées,
> Osa du firmament diviser les contrées.’
>
> Chênedollé.

Looking at the Pole Star, stationary in the midst of the northern region, we have the south behind us, the east to the right, the west to the left. All the stars revolving round the Pole Star, from right to left, ought to be recognised according to their mutual relations rather than according to the cardinal points. On the other side of the Pole Star, relating to the Great Bear is another constellation easily recognised. If a line be brought to the pole, from the star in the middle ( ), by prolonging this line to an equal extent, the figure of Cassiopea is crossed, which is formed of five stars of the third magnitude arranged somewhat like the slanting strokes f the letter M. The little star κ, which ends the square, also gives it the form of a chair. This group takes every possible position, going round the pole; sometimes being above, sometimes below, sometimes to the left, and sometimes to the right: but it is always easy to find, seeing that, like the preceding constellation, it never sets and is always opposite to the Great Bear. The Pole Star is the axle around which these two constellations revolve.

If we now draw, from the stars *α* and *δ* of the Great Bear, two lines joining the pole, and we prolong these lines beyond Cassiopea, they will lead to Pegasus, which is terminated on one side by a row of three stars similar to those of the Great Bear. These three stars belong to Andromeda, and themselves lead to another constellation, Perseus. The last star of the square of Pegasus is, as we have seen, *α* Andromedæ; the three others are called. *γ*, Algenib, *α*, Markab, and *β*, Scheat. To the north of *β* Andromedæ is found, near a little star, *ν*, the oblong nebula which has been compared to the light of a candle seen through a horn plate, the first nebula of which mention is made in the annals of astronomy. In Perseus, *α*, the most brilliant star in the prolongation of the three principal stars of Andromeda, is seen between two others less brilliant, which with it forms a concave arc very easily distinguished.

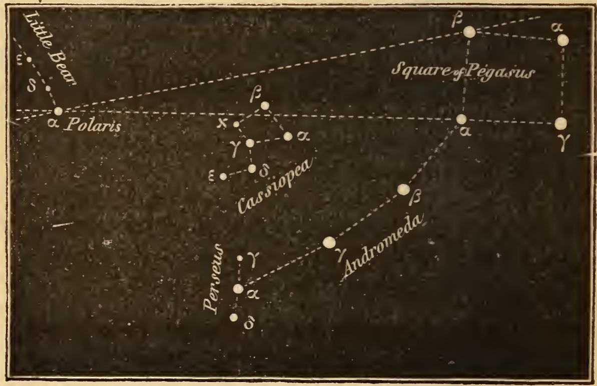

Fig. 16. Cassiopea, Andromeda, Pegasus.

This arc will now serve us as a new starting-point. By continuing it from δ, a very brilliant star of the first magnitude, is met with; this is the Capella. Forming a right angle with this prolongation to the south, we arrive at the Pleiades, a brilliant cluster of stars. On one side is a variable star, Algol, or the Head of Medusa.

The star Algol or β Persei, which is seen above α, belongs to a class of variable stars, the singular character of which we shall consider further on. Instead of having a fixed light, as other stars, it is sometimes very brilliant and sometimes very faint; it passes from the second to the fourth magnitude. It was at the end of the seventeenth century that this variability was first perceived. Observations made since that time have proved that it is periodical and regular, and that this period is of astonishing rapidity. Thus, to pass from its minimum to its maximum brilliancy, it only requires one hour and three quarters, so that in three hours and a half it has accomplished its entire cycle, has passed through all the intermediate degrees of light from the fourth to the second magnitude, and from the second to the fourth. The star ζ of Perseus is double.

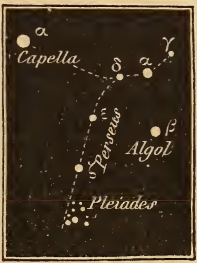

Fig. 17. The Goat, Pleiades.

These are the principal stars which people the circumpolar regions, on the one side; presently we shall make better acquaintance with them. Whilst we are tracing lines of indication, let us have patience and finish our short examination of this part of the sky. Take now the opposite side to the one we have just considered, still near the pole. Let us return to the Great Bear. Prolonging the curve of the tail we shall find at some distance from it a star of the first magnitude, this is Arcturus or α of the Cow-herd (Boötes). A small circle of stars that we see to the left of Boötes forms the Northern Crown.

The constellation of Boötes is traced in a pentagonal form. The stars which compose it are of the third magnitude, with the exception of α, which is of the first. This is the one nearest the Earth, for it is of the small number of those whose distance has been measured. It is situated at 1,622,800 times the radius of the Earth's orbit from us. It is, moreover, a coloured star; seen with a telescope, it is red. The star ε, which is seen above it, is double, that is to say, the telescope separates it into two distinct stars: one being yellow, the other blue.

By bringing a line from the Pole-Star to Arcturus, and erecting a perpendicular on the middle of this line, opposite to the Great Bear, we find one of the most brilliant stars of the heavens, Vega, or α of the Lyre, near the Milky Way. It forms with the two just mentioned a large equilateral triangle. The line from Arcturus to Vega cuts the constellation of Hercules. Between the Great and Little Bear, a long series of little stars is seen passing round each other in rings and directing themselves towards Vega: these are the stars of the Dragon.

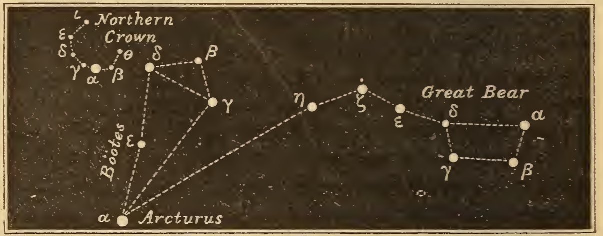

Fig. 18. Northern Crown, Boötes, Arcturus.

The stars bordering on the pole, and which have therefore received the name of Circumpolar Stars, are distributed into the groups we have just described. Now that we easily know how to find them in the sky, we may speak a little of their ancient renown. In this group there is one of the greatest dramas of ancient mythology. To repeat this famous episode in a few words, I will mention that Cassiopea, wife of Cepheus, king of Ethiopia, one day had the vanity to believe herself more beautiful than the Nereides, in spite of the African colour of her complexion. These sensitive nymphs, piqued to the quick by such pretensions, prayed Neptune to avenge them of such a gigantic affront; the god allowed fearful ravages to be made by a sea-monster on the coasts of Syria. To stay the plague, Cepheus chained his daughter, Andromeda, to a rock and offered her in sacrifice to the terrible monster. But young Perseus, touched with so much misfortune, quickly bestrode the horse Pegasus, a model of coursers, took in his hand the Medusa's head, which froze the beholder with fright, and started for the fatal rock. He arrived naturally just at the moment when the monster was going to devour his prey, and nothing was more easily done than to petrify the monster by presenting Medusa's head to him, and to liberate the fainting Andromeda. This is a scenic effect from which painting has derived advantage in every sense; there are perhaps as many Andromedas as Ledas, and these are innumerable. It must be owned also that the painter has not often so captivating a subject. The combat of Perseus with the monster is without equal in history.

'Le héros fond sur lui sans se laisser attendre,
S'élève, redescend, frappe encor, mais en vain.
L'écaille impénétrable a repoussé l'airain.
Le monstre est en fureur; Andromède éperdue
De cet affreux combat veut détourner la vue,
Pousse un cri lamentable, et, levant ses beaux yeux,
Retrouve son vengeur qui plane dans les cieux,
La fille de Céphée, en sa douleur mortelle,
Pleure, frémit de crainte, et, ce n'est plus pour elle.
Mais enfin le héros vers le monstre abhorré
Précipite son vol, et d'un bras assuré

> Dans sa gueule béante enfonce cette épée
> Du sang de la Gorgone encore toute trempée.
> C'en est fait : à ses pieds revoyant son vengeur,
> Andromède a senti redoubler sa rougeur ;
> Les dieux sont satisfaits ; et près de lui placée,
> Jusqu'au brillant Olympe elle a suivi Persée.
> Par quels plus beaux exploits monte-t-on dans les cieux ?'
>
> DARU.

In commemoration of these exploits, and not to give one an advantage over the other, all the family were placed in the heavens, and still remain there. With a little inclination, and knowing pretty well the conventional figures which divide our celestial atlas, we can see under the starry dome Cepheus enthroned, crown on head and sceptre in hand; at his side his wife Cassiopea, seated on a chair ornamented with palms; a little further on Andromeda, chained to a rock in the midst of an abyss; an immense fish attacks her on one side; Pegasus flying in the air a little in front; and, lastly, the hero of the piece, Perseus, holding in the right hand a curved sword, and in the left the head with the hideous serpents. This is what the mythological eye may still contemplate at midnight during the beautiful season of summer.

Boötes is seen above the Virgin on the zodiacal map. He was called Arcas, and was the son of Jupiter and Callisto. He was also called Atlas, who carries the world, because, formerly, his head was close to the pole. As the Pleiades rise when Boötes sets, it has also been said that they were his daughters. In its vicinity shines like golden rain Berenice's Hair. It will be remembered that 246 years before Christ, Queen Berenice, who made a vow to cut off her hair if Ptolemy Euergetes, her husband, returned victorious, consecrated it to the gods in the temple of Venus, after the victory of the prince. Her husband was very displeased with this unlucky idea, and it was feared that he would not be able to calm his passion, the more so, as the queen's hair was stolen the following night; but the astronomer

Conon assured him that the regretted hair had been transported to the sky by order of Venus, and actually shone as a constellation.

> ‘Le mortel qui, des cieux écartant tous les voiles,
> Calcula le lever, le coucher des étoiles,
> Conon me fit voler, par la faveur des dieux,
> Du front de Bérénice à la voûte des cieux.
> Humide encor des pleurs de ma reine fidèle
> Je montai, nouveau signe, à la voûte éternelle ;
> Admise entre la Vierge et le cruel Lion,
> Je guide à l’occident, en sa route incertaine,
> Le Bouvier qui vers l’aube à pas pesant se traîne.’
>
> CATULLUS.

The Hunting Dogs, or Greyhounds, are not distinguished by any remarkable star, but they possess the most beautiful nebula in the sky: that which I have before described and pictured (p. 35). It is situated in the left ear of Asterion, the northern Hunting Dog. As this left ear touches the tail of the Great Bear, it is easy to find it under the last star of the tail. To discern its form a good telescope is required. This is the nebula which resembles the Milky Way at a distance, and which was for some time considered as a globular cluster surrounded with a ring, until the day when Lord Rosse’s great telescope showed it as the most magnificent spiral nebula in the heavens.

## III.

## THE ZODIAC.

> ‘Le ciel devint un livre où la Terre étonnée
> Lut en lettres de feu l’histoire de l’année.’
>
> Rosset.

It is known that the Sun in its apparent path above our heads, follows a regular and permanent course; that each year, at the same periods, it passes at the same height in the sky, and that it is not so high in the month of December as in the month of June; the path it pursues is not less regular on that account, as it rises and falls in its circuit and at the same periods it always returns to the same points in the heavens. It is also known that the stars remain perpetually around the Earth, and, if they disappear in the morning, to shine again in the evening, it is only because the daylight effaces them. Now, the term *zodiac* is given to the starry zone through which the Sun passes during the entire course of the year. This word comes from *ζώδιον, animal*, an etymology taken from the character of the figures traced on this band of stars. Animals, indeed, predominate in these figures. The entire circumference of the heavens has been divided into twelve parts, which have been named the twelve signs of the zodiac, and our forefathers called them the ‘houses of the Sun,’ and again ‘the monthly residences of Apollo,’ because the Sun visits one each month, and returns each spring to the commencement of the zodiacal cortege. Two Latin verses give these twelve signs in the order in which the Sun crosses them,—

> 'Sunt: Aries, Taurus, Gemini, Cancer, Leo, Virgo,
> Libraque, Scorpius, Arcitenens, Caper, Amphora, Pisces.'

Or rather in English: the Ram ♈, the Bull ♉, the Twins ♊, the Crab ♋, the Lion ♑, the Virgin ♏, the Scales ♎, the Scorpion ♍, the Archer ♐, the He-goat ♄, Aquarius ♒, and the Fishes ♓. The signs placed by these names are the primitive indications which bring them to mind: ♈ represents the horns of a ram; ♉ the head of a bull; ♒ is a stream of water.

If we have now become acquainted with our northern heavens, if its most important stars are sufficiently marked in our mind and their reciprocal relations with each other, we need no longer fear confusion, and it will be easy to recognise the zodiacal constellations. We must note especially that they all belong to one zone, to one belt of the sky, which may serve us as a line of division between the north and south. An easy method of finding this zone in a fine starry night, and to avoid useless search, is to take the Pole Star as the centre of a large circle, and to describe this circle by taking a radius equal to the half of the sky. The line thus described will extend beyond the zenith to the south, and will descend below the horizon to the north; it will mark therefore the celestial equator. Now the ecliptic, on the meridian line of the zodiac, is slightly inclined to the equator, but it only goes beyond it a little, so that our circle will give us, with sufficient exactitude, the line towards which we must look for our constellations.

These summary indications once given, the first signs will be easy to find. To have a complete and lasting knowledge of them, it is necessary to follow the description I am going to give on the accompanying maps, and afterwards in the evening to study the originals directly, of which the maps are only copies. These same maps will again serve us, in the following chapter, in studying the southern constellations visible in England.

The Ram is situated between Andromeda and the Pleiades which we already know. By drawing a line from Andromeda to this group of stars the head of the Ram is traversed, formed by two stars of the third magnitude, arranged in a north-east direction. The Ram is the first sign of the zodiac, because, at the time when this principal part of the celestial sphere was established, the Sun entered this sign at the spring equinox. In the fable, it represents the Ram with the golden fleece of the Argonaut expedition, because at the moment when the Sun rises in this sign, guarded by a monster (the Whale) and by a Bull which vomits flames, the constellation Ophiuchus or Jason, comes out in the evening at the same point, and thus subjugates the vanished Ram. The Ram was also the symbol of Spring and the opening of the year. These two causes were indicated by the translator of Plutarch. The Bull comes afterwards. We go from west to east. We shall easily recognise it by the group of the Pleiades which sparkle on its shoulder, by that of the Hyades which glimmer on its forehead, and by the magnificent star which marks its right eye, the star Aldebaran, $\alpha$, of the first magnitude. It is, moreover, situated just above the splendid constellation of Orion, which we shall meet again and make acquaintance with soon; Aldebaran shines along the line of the Belt to the north-west. (To follow our map.)

The Pleiades, which are seen trembling at the north-west of Aldebaran, are a group of about 80 stars, resolved by the telescope.

The ancients counted in the Pleiades seven stars more brilliant than the ground sprinkled with golden dust. At the present time only six can be counted with the naked eye, which are called,—Alcyone or $\eta$ in the neck of the Bull, of the third magnitude; Electra and Atlas, of the fourth; Merope, Maïa and Taygeta, of the fifth. If we are to believe Ovid, the seventh hid itself with grief at the taking of Troy. But the author of the 'Metamorphoses' suspected nothing of the distance of stars and the length of passage of the rays in reaching us. If even one of the Pleiades hid itself at the taking of Troy, Ovid would still have seen it in the place which it formerly occupied, and perhaps even now we should have still seen it there. The Hyades form a V with Aldebaran, which occupies the southern extremity. Like the Pleiades, they announce rain; their name signifies *to rain*, and that of their companions signifies *navigator*. This inspired J.-B. Rousseau with the following verses:—

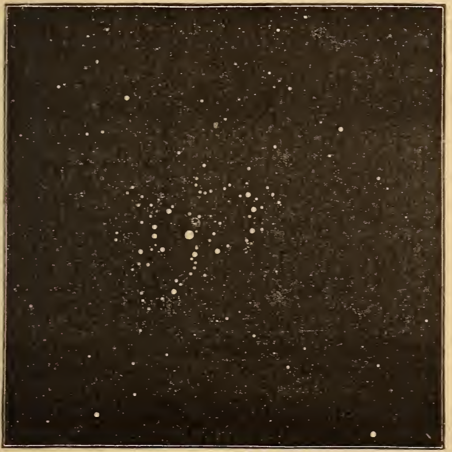

Fig. 19. The Pleiades.

'Déjà le départ des Pléiades
A fait retirer les nochers,
Et déja les tristes Hyades
Forcent les frileuses Dryades
De chercher l'abri des rochers.'

The Twins are easy to recognise to the east of the preceding stars, their heads being formed of two beautiful stars, Castor and Pollux. We shall also reach them by a diagonal, crossing the Great Bear. Again, Castor, of the first magnitude, forms a triangle with the Goat and Aldebaran. Therefore, nothing is more easily found. Descending towards the Bull, eight or ten stars terminate the constellation, and lower down, Procyon is met with, a star of the second magnitude. This region, marked with Orion, Sirius, the Twins, the Goat, Aldebaran and the Pleiades, is the most magnificent region of the celestial sphere. It is towards the end of Autumn that it shines in our hemisphere in the evening. The Twins are, in the fable, Castor and Pollux, sons of Jupiter, celebrated for their indissoluble friendship, for which they were rewarded by immortality. The changes of fortune have been compared by the poet to the destiny of these two brothers:—

'Jupiter fit l'homme semblable
A ces deux Jumeaux que la Fable
Plaça jadis au rang des dieux ;
Couple de déités bizarre,
Tantôt habitants du Ténare,
Et tantôt citoyens des cieux.'

The Greeks also gave the name of Castor and Pollux to those lights which appear round vessels after storms, electrical phenomena now called the fires of Saint Elmo.

The Crab or Cancer may be distinguished at the bottom of the line of Castor and Pollux, in five stars of the fourth or fifth magnitude. It is the least important body of the zodiac:—

'La timide écrevisse à la serre traînante
Annonce le retour de la saison brûlante :
Son aspect, qui pour nous borne les plus longs jours,
Fait du char du soleil rétrograder le cours.'

While Hercules was fighting the Lion of Nemea, the Crab, aiding the vengeance of Juno, pinched the heel of the hero, who crushed it with his foot, but the queen of heaven gave it its reward by placing it in the heavens.

The Lion is a large trapezium of four beautiful stars, situated to the east of the Twins. They may readily be found by continuing in the opposite direction the line, from $\alpha$, $\beta$ of the Great Bear, which served us to find the Pole Star. The most brilliant of these stars, $\alpha$, is of the first magnitude and is called Regulus, the heart of the Lion; the three others, $\beta$, $\gamma$, and $\delta$ are of the second magnitude. The Sun enters the Lion at the summer solstice, and causes it to disappear by covering it with his fires; this is the victory of Hercules over the Lion of Nemea. It was also for the same cause the symbol of strength and power. Being the abode of the Sun during the month of July, it was again the sign of burning heats and of plagues which they sometimes brought with them. In the eyes of astrologers of the middle ages, this was its terrible aspect. The Virgin comes after the Lion, still to the east, as will be seen on the map. If we again use the very accommodating constellation which has until now been so useful to us, we must continue towards the south the great diagonal $\alpha$, $\gamma$ from the square of the Great Bear, and we shall meet with a beautiful star of the first magnitude placed just to the left of our figure; this is the Virgin's ear of corn, or Spica, a star known from all antiquity. Now that we can distinguish Arcturus, or Boötes (p. 70), and $\alpha$ of the Lion, we may also remark, that these two stars and Spica form together an equilateral triangle. The star $\beta$, situated in the right arm of the Virgin, is called the Vintager. It forms a triangle with $\beta$ of the Lion and Berenice's hair.

Emblem of justice and law, the Virgin represents Themis, with the scales at her feet. Why has she wings? Perhaps because Justice, formerly on the earth, abandoned it for heaven. She is also Astrea, daughter of Jupiter and Themis, men's crimes having forced her to return to heaven at the end of the golden age. She has the privilege of representing a great number of persons; the entire list would be too long, the following being only a few of them: Ceres, symbol of harvests; Diana of Ephesus; Isis of Egypt, goddess of Syria; Atergatis or Fortune; Cybele drawn by lions; Minerva, mother of Bacchus; Medusa; Erigona, daughter of the Cow-herd; lastly, in the time of Virgil, she was the Sybil, who, with branch in hand, descended to the infernal regions. With so large a choice, she seems to have preferred the title of Daughter of Justice, exiled to the celestial regions by man's crimes.

The Scales is the seventh sign of the zodiac. To the east of Spica, two stars of the second magnitude are seen; these are $\alpha$ and $\beta$, marking the top of the Scales. With two other less brilliant stars, they form an oblique square on the ecliptic. Two thousand years ago, the Sun passed them at the autumnal equinox, and this is the origin of that sign which 'equals the day to night, work to sleep.'

J.-B. Rousseau expresses the same idea in one of his odes:—

> 'Le soleil, dont la violence
> Nous a fait languir si longtemps,
> Arme de feux moins éclatants
> Les rayons que son char nous lance,
> Et, plus paisible dans son cours,
> Laisse la céleste Balance
> Arbitre des nuits et des jours.'

The Scorpion, with its heart marked by the brilliant Antares, a star of the first magnitude, is easily recognised. It is not that the form can be distinguished; for this form is not better sketched out by the stars which compose it, than the preceding figures, the Scales, the Virgin, &c. have been. But it is well understood that, when we speak of recognising a constellation, we refer simply to the groups of stars which bear its name and not to its mythological figure. Antares, $\alpha$ of the Scorpion, is on the continuation of the line which would join Regulus ($\alpha$ of the Lion) to Spica: these are three stars of the first magnitude placed in a straight line, in a west-east direction. Antares also forms with Lyra and Arcturus a large isosceles triangle, the latter star being at the vertex. The second star of the Scorpion, $\beta$, of the second magnitude, marks the head. A string of stars of the third magnitude traces out the curved tail.

The Scales and Scorpion only formed one sign with the Latins before Augustus: the Scales were then the claws of the Scorpion. As Augustus was born on the 23rd of September, flattery leagued itself with astrology to celebrate the happiness promised to the Earth by the birth of this emperor; the Scales, which the Egyptians had formerly instituted in the original sphere, were replaced in the heavens as a symbol of Justice.

The verses of the Eneid may now be easily interpreted. As a sign of misfortune and fear, the Scorpion was cursed among all the constellations. It was said, especially, that it had an invincible hatred towards Orion, because this figure sets when the former rises, and *vice versâ*. It was not only the terror of the stars, but also the terror of the Sun himself, that Ovid has described it to us.

Sagittarius (the Archer), forming an oblique trapezium, is a little to the east of Antares, still following the direction of the ecliptic. It only contains stars of the third and less magnitudes; $\sigma$, $\delta$, $\gamma$, form the arrow; the last, $\gamma$, is called Nushaba by the Arabs. The star $\pi$ marks the head. This constellation never rises much above the horizon of London. In the fable, it is the Centaur Chiron, the tutor of Achilles, Jason, and Esculapius, and the inventor of the art of riding. This was the last lord of this ancient race. Doubtless, the vicinity of the Scorpion influenced the opinion of the poets with regard to itself, for it is not represented under very favourable colours.

> ‘Déjà du haut des cieux le cruel Sagittaire
> Avait tendu son arc et ravagé la terre ;
> Les coteaux, et les champs, et les prés défleuris,
> N’offraient de toutes parts que de vastes débris ;
> Novembre avait compté sa première journée.’

Capricornus (the He-goat) is not rich in bright stars. Those which sparkle on his forehead, $\alpha$ and $\beta$, are the only ones which can be distinguished by the naked eye. They are on the continuation of the line which passes from Lyra to the Eagle. The region of the Zodiac which we are now visiting is the poorest in the heavens ; it presents a striking contrast with the opposite region, where we admired Aldebaran, Castor and Pollux, the Goat, &c.

Above Capricornus shines Altair, or $\alpha$ of the Eagle : the stars of Antinoüs form a trapezium on the path from Capricornus to the Eagle. In some authors, this sign represents the goat Amalthea, which nursed Jupiter on Mount Ida, and received a place in heaven as a reward. According to others, it represents the return of the Sun to the winter solstice through the gates of the tropics. Again, according to others, it was a he-goat which was brought up with the king of the gods, and which discovered and sounded the marine trumpet, and produced fear among the Titans in their war with Olympus. The frightened gods hid themselves in the forms of different animals ; Apollo changed into a crane, Mercury into an ibis, Diana into a cat. Such a metamorphosis was never seen. Lastly, Pan into Capricornus, having a goat’s body and the tail of a fish. He appeared, also, to wish to steal away with the giants who scaled heaven.

Aquarius forms with his three tertiary stars a very obtuse triangle. The base is prolonged in a string of stars from the side of Capricornus and towards the left to the Urn. Thence begins a sinuous line of very small stars descending to the horizon. This is the water poured out by Aquarius.

Aquarius appears to personify Ganymede, who was raised by Jupiter's eagle to serve as cupbearer to the gods after the fall of Hebe.

> 'Jupiter, qui d'Hébé prononce la disgrâce,
> Au jeune Ganymède a destiné sa place ;
> Le nouvel échanson, hôte digne des cieux,
> De torrents de nectar enivre tous les dieux.'

The Fishes, the last sign of the Zodiac, lie to the south of Andromeda and Pegasus. The northern fish is that which wished to devour Andromeda; the western fish advances in the square of Pegasus ; they are bound together by a band. Not so apparent as the preceding, this constellation is composed of two rows of very small stars, which start from $\alpha$ of the third magnitude, the knot of the band, and diverge, one towards $\alpha$ of Andromeda, the other towards $\alpha$ of Aquarius. Ovid tells how Venus and Love, wishing to steal away at the pursuit of the giants, crossed the Euphrates on two fishes, which were for this placed in heaven. It is related that two fishes having found an egg of a very beautiful shape, drew it to shore, that a dove sat on it, and Venus came forth. It was from this time that the Syrians abstained from feeding themselves on fish. This sign is the last abode of the Sun before the renewing of the year, in the month of February ; this was the time of the inundation of Egypt and that of fishing with us. It closes the circle of the zodiacal constellations.

> 'Enfin aux derniers rangs paraissent les Poissons,
> Qui, fermant à la fois et rouvrant les saisons,
> De l'hiver rigoreux tempèrent l'influence,
> Et d'un nouveau printemps raniment l'espérance.'
> RICARD.

If our descriptions have been well followed on our map, the zodiacal constellations will be as well known as those of the north. Little now remains before we become familiar with the whole heavens, yet there is an indispensable complement to the preceding. The circumpolar stars are always visible above the London horizon; at any time of the year that we wish to observe them, they may always be found, either above, below, or on one side or the other of the Pole Star, which has served us to find them, and always preserving the same relation one with the other. The zodiacal stars do not resemble them in this point of view; for they are sometimes above the horizon and sometimes below it. We must, therefore, know at what time they are visible. For this it will be sufficient to remember the constellation which is at the centre of the heavens at nine o'clock in the evening, on the first day of every month, that, for instance, which at that hour crosses a line drawn from the Pole Star, from north to south, dividing the sky into two parts. This line is called the meridian, and all our figures cross it, passing from east to west. Marking each of the constellations which pass at the indicated hour, we thus give the centre of the visible constellations. Looking for the northern ones at the north; to its left those which precede the indicated constellation in the order of the signs; to its right those which follow it, all will be found without difficulty. On the first of January the Bull passes the meridian. Notice Aldebaran and the Pleiades.—1st of February: the Twins have not yet reached there, they are seen a little to the right.—1st of March: Castor and Pollux have passed, Procyon at the south: the little stars of the Crab to the right.—1st of April: the Lion, Regulus.—1st of May: β of the Lion, Berenice's Hair.—1st of June: Spica of the Virgin, Arcturus.—1st of July: the Scales, the Scorpion.—1st of August: Antares, Ophiuchus.—1st of September: Sagittarius, the Eagle.—1st of October: Capricornus, Aquarius.—1st of November: the Fishes, Algenib or γ of Pegasus.—1st of December: the Ram.

Our general revision of the starry heavens ought now to be completed by the stars of the Southern sky.

I have only given a rapid summary of the mythological explanation of the signs of the Zodiac; the uncertainty which reigns over their origin has allowed many to be suggested. I shall only recount here, that which supposed them to be the twelve labours of Hercules, a suggestion which does not lack a certain ingenuity. Hercules would be no other than the Sun himself considered in his attributes relatively to the different times of the year. Francœur, in his *Uranographie*, according to Lalande and the philosopher Dupuis, charged himself with supporting this curious system.

The entrance of the Sun into the solstitial Lion which he made to disappear by covering it with his fires, is the victory over the Lion of Nemea. In proportion as the Sun advances he crosses Cancer, the Lion, and the Virgin; the different parts of the Hydra are eclipsed by turn; first the head, then the body, and lastly the tail; but then the head reappears in its heliacal rising. This is the triumph over the Hydra rising again from the Lake Lerna, which Hercules burned, after having crushed the Crab which aided it. The Sun crossing the Scales at the time of the vintages covers the Centaur with his fires. The fable states that the Centaur Chiron, having received Hercules, taught him the art of making wine. It adds that, in a drunken dispute, the people of the Centaurs wished to kill Hercules' host, which forced the hero to fight with them; this appears to relate to the setting of Sagittarius in the evening. Lastly, in hunting, he conquered a monster, called the wild boar of Erymanthus, which was believed to refer to the rising of the Great Bear in the evening.

Cassiopea, who is represented also by a hind, in the morning sets in the waves when the Sun is in Scorpion, which happens at the autumnal equinox; it is this hind with golden horns which, in spite of its wonderful velocity, Hercules tired out in a race, and caught at the water's edge when she reposed.

At the rising of the Sun in Sagittarius, the Eagle, Lyra (or the Vulture), and the Swan situated in the Milky Way, disappear at once; these are the birds of the Lake Stymphalis, driven out of Arcadia by Hercules, whose arrow is placed among them. Capricornus, or the celestial He-goat, is bathed in front by the water of Aquarius; these are the stables of Augias cleansed by a river passing through them.

The Sun in Aquarius, or the winter solstice, was near Pegasus; in the evening the Vulture was seen to set, whilst the Bull passed the meridian; it was said that Hercules, on his arrival in Elis, to fight the Bull of Crete and the Vulture of Prometheus, mounted the horse Arion and instituted the Olympic Games, which are celebrated at full moon of the summer solstice; the moon is then exactly in Aquarius, that is to say, in the region opposite to the Lion. The carrying off of the mares of Diomedes, son of Aristes, relates to the heliacal rising of Pegasus and the Little Horse, the Sun being in the Fishes. These two Horses are placed above Aquarius, which is Aristes.

Hercules afterwards starts for the conquest of the Golden Fleece, Aquarius and Serpentarius rise in the evening, whilst at the same time the Ram, Cassiopea, Andromeda, the Pleiades, and Pegasus set. Hence the victory of Hercules over Hippolyte, queen of the Amazons, whose belt (Mirach) shines with a bright light. Many of these warriors had the names of the Pleiades.

At the rising of the Bull, the cow-herd (Boötes) sets, and the Great Bear (the oxen of Icarus) rises. This is the defeat of Geryon and the carrying off of his oxen. Hercules kills Busiris, persecutor of the Atlantides: the fable which alludes to Orion pursuing the Hyades, and who is then hidden in the solar beams. The return of Spring is moreover explained by the destruction of the venomous reptiles of Crete and by the defeat of the brigand Cacus; that of the river Achelaüs, changed into a bull, relates to Eridanus, which is situated below.

After having founded Thebes in Egypt, Hercules went to the infernal regions, delivered Theseus and carried off Cerberus. The Sun has arrived in the northern hemisphere; the Great Dog, whose heliacal setting took place in the preceding sign, is now absorbed in the Sun's brightness; he is taken from the infernal regions, and brought to the light. The river of Aquarius, which rises in the evening with the Swan, when the Sun has traversed the constellation of the Twins, is Cycnus conquered at the borders of Penea.

The Northern Dragon and Cepheus, or the garden of Hesperides, rise at the setting of the Sun, under Cancer; hence the voyage of Hercules in Hesperia. The time of the heliacal rising of the constellation of Hercules is in autumn; the apples of the Hesperides are an allusion to this season.

Returned to the summer solstice, the Sun recommences its revolution: this is the apotheosis of Hercules. Fable relates that Dejanira, seeking for a love-potion to keep her husband, sent him a shirt soaked in the blood of the Centaur Nessus. Hercules put it on to sacrifice to the gods, and to ask of them the immortality promised for his exploits; but, devoured by the poison in the garment, the hero burnt himself on the funeral pile. This is the sense of this fable. The Sun has entered the Lion and rises, whilst the constellations Hercules and Aquarius are about to set. The Centaur sets a little after the Lion; this one then causes Hercules to die, and Aquarius, Ganymede, is carried off to pour out nectar to the gods, in the place of Hebe, given to the hero. The reconciliation of Hercules and Juno relates to Aquarius, who is dedicated to the goddess.

Hercules lived 52 years, had 52 wives and accorded the Nemean honours to 360 of his companions who died for him: this alludes to the 52 weeks of the year and to the 360 degrees of the Zodiac. The Pillars of Hercules were the western limits of the known Earth, where the Sun seemed each day to set in the sea.

However vague many of the interpretations just put forth may seem to be, adds Francœur, there are some so remarkable that they cannot be supposed to be altogether the effect of chance: thus Hercules was not a hero whose good actions excited men to erect altars to him; but the Sun, considered in his attributes relative to the different epochs of the year; an opinion agreeing with the mos revered testimonies of the ancients.

# IV.

## THE SOUTHERN CONSTELLATIONS.

> ‘Qui donc sur l’Océan, dans l’ombre et le silence,
> Elève avec orgueil son front majestueux;
> Et, bravant de Phœbé le disque lumineux,
> Devant son trône même insulte à sa puissance?
>
> ‘C’est toi, noble Orion: tes feux étincelants
> Des soleils de la nuit effacent la lumière,
> Comme le dieu du jour, entrant dans la carrière,
> Efface de Phœbé les rayons pâlissants.
>
> ‘Sur le trône des airs fais briller la couronne;
> Viens, héros indompté, régner sur nos climats,
> Lève-toi! que nos yeux attachés à tes pas
> Contemplent à loisir l’éclat qui t’environne.
>
> ‘Perçant des sombres mers les nocturnes brouillards
> Sous l’orgueilleux fardeau de ta pesante armure,
> Je te vois déployer ta superbe ceinture
> Et de l’homme étonné commander les regards.
>
> ‘Le Taureau loin de toi recule épouvanté:
> Il roule avec effroi sa prunelle sanglante;
> Tandis que vers le nord s’enfuit l’Ourse tremblante
> Aux éclairs menaçants de ton glaive irrité.’*

‘A TOUT seigneur tout honneur.’ Orion is the most beautiful constellation; we must not pass it without doing homage to it, and the best way of rendering homage to persons of worth, is to learn how to understand them.

Let us observe our map: below the Bull and the Twins, to the south of the Zodiac, you will notice this giant who raises his club towards the forehead of the Bull. Seven bright stars are distinguished; two of them, α and β, are of the first magnitude; the other five are of the second; α and γ mark the shoulders, χ the right knee, β the left foot; δ, ε, ζ mark the belt; below this line is a luminous train of three stars close together, this is the Sword. Between the western shoulder, γ, and the Bull, is seen the Shield composed of a curved string of little stars. The head is marked by a little star, λ of the fourth magnitude; μ and ν denote the raised arm.

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* Newland, quoted by Quételet in his *Astronomy*.

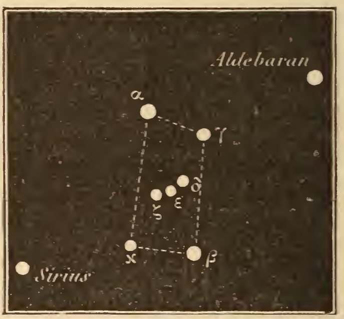

Fig. 20.—Orion, Aldebaran, Sirius.

For more clearness, we give the arrangement of the principal stars of this magnificent asterism.

Orion is on the continuation of the line which joins the Pole Star to Capella. The four stars, α, γ, β, ϰ, occupy the angles of a great quadrilateral; the three others δ, ε, ζ are close together in an oblique line in the middle of this quadrilateral; α, in the north-east angle is called Betelgeuse (not Beteigeuse, as generally printed), β, of the south-west angle, is called Rigel.

The line of the Belt, prolonged on both sides, passes on the north-west by the star Aldebaran in the eye of the

Bull, which we already know, and on the south-east by Sirius, the most beautiful star in the heavens, with which we shall soon occupy ourselves. It is during fine winter nights that this constellation shines over our heads. No other season is so magnificently constellated as the winter months. Whilst nature deprives us of certain enjoyments on the one hand, it presents us with others no less precious. The wonders of the heavens present themselves to amateurs from the Bull and Orion at the east, as far as the Virgin and Boötes at the west; of eighteen stars of the first magnitude, which may be counted in the whole extent of the firmament, a dozen are visible at nine o'clock in the evening, not counting many beautiful stars of the second order and the remark able nebulæ and heavenly objects very worthy of the attention of mortals. These twelve stars are: Sirius, Procyon, Capella, Aldebaran, Spica, the heart of the Hydra, Rigel, Betelgeuse, Castor and Pollux, Regulus, and β of the Lion.

Thus it is that nature establishes everywhere harmoniou compensation, and whilst it darkens our short and frost winter days, it gives us long nights enriched with the wealthiest creations of the heavens.

The constellation of Orion is not only the richest in bright stars, but it conceals also treasures for the initiated which no other can present. We might almost call it the California of the heavens. We will enumerate its riches, and shall then find greater delight in contemplating it in the heavens.

Let us speak first of its nebula, situated below the second star of the Belt. The first time that Huygens, its discoverer, admired this cosmical beauty, in 1656, he was sufficiently astonished to say, that it seemed an opening in the sky which threw light on a more brilliant region. 'Astronomers,' he states, 'have counted in the sword of Orion three stars very near each other. In 1656, I accidentally observed that, in place of one of these stars which occupy the centre of the group, there was a dozen of them, a result which is not rare to obtain with telescopes. Of these stars there were three which, like the first, nearly touched each other, and four others seemed to shine through a cloud in such a manner that the space which surrounded them appeared much more luminous than the rest.'

Since that period this nebula has been studied with a kind of predilection; it has been minutely examined and the different regions of its cluster have been studied and described in all their details. In proportion as the instruments have become more powerful, the stars, which constellate it, appear more numerous, which has happened in all telescopic observations of nebulæ; and, whilst in early days it was asked with great uncertainty if there was only a phosphorescent cloud, a vaporous mass—astronomers afterwards arrived at the conviction that it was formed of an immense number of heaped-up suns, and then again that it was a true cosmical cloud. At the centre is seen a brighter part of singular form; Sir J. Herschel compared it to the head of a monstrous animal, with gaping mouth, the nose being prolonged like the trunk of an elephant.

It occupies a large space in the sky, its apparent dimension being equal to that of the lunar disc. When we think of the distance which separates us from this agglomeration, we are dismayed at the real extent which it embraces in the midst of the boundless void.

But the strangest phenomena which are attached to this nebula are the changes which are observed in it. The drawings which are now taken differ from those which were taken half a century ago. Again this year (1867), there has been noticed in England an indication of brightness, through a dark portion, which did not exist ten years ago. Astronomers agree that there is no possible delusion in some of these observations, and that this distant agglomeration is the seat of formidable disturbances.

'The general impression that I have received from these observations,' said the director of the Russian Observatory not long ago, 'is that the central part of the nebula is in a state of continual agitation, like the surface of the sea.'

Orion possesses many other riches. The star of the left foot, Rigel, is one of the most beautiful double stars. (We shall soon commence this chapter of Sidereal Astronomy.) This double star is composed of a white and a blue sun. In calm and clear nights which we sometimes have in the winter, it appeared to me sometimes that the reflection of the blue star tinted the brightness of the white sufficiently to cause this to seem slightly tinted with blue, especially when it is compared with the golden points which sprinkle the surrounding sky.

Two other binary systems are met with in the two stars at the extremities of the Belt. The first to the right is composed of a white and a purple sun; the second, of a yellow and a blue sun. Thus here are three systems of the most dissimilar worlds united in the same constellation. In each of these systems two suns instead of one; not only two suns like ours, but two differently coloured suns; in the planets which belong to the first, a white and a blue body dispute the empire of the day with each other, giving rise, by the numberless combinations of their heat, light, and electrical power, to a variety of actions incomparable and unimaginable by us, who are devoted to one sun. In the planets which belong to the second, it is a purple sun which diversifies the white light of its compeer. In that of the third the number of colours is essentially different from ours, as there is no white light the generator of every tint; and presents an unknown series of shades, the result of the combinations of gold and sapphire. These planets are doubtless green, and the colour of the objects on their surface must probably oscillate round this medium either as yellow or blue.

But this wealth of stellar systems does not yet constitute all the patrimony of this beautiful constellation of Orion. It contains, besides, the most complex of multiple systems which have ever been met with in the heavens. In the nebula of which I have just spoken, an extraordinary star is met with, the star marked $\theta$ in the catalogues, a little below the Sword. This star, divided by the telescope, presents to our admiration six suns collected in one point of the heavens. Four principal stars of the fourth, sixth, and seventh magnitudes, are arranged at the four angles of a trapezium ; the two stars at the base have each a very feeble companion. That these six stars form in reality a physical system and that they are connected together, like the binary systems, by the law of attraction, is a statement I do not wish to affirm. It may be that this is only an optical effect—that these six stars are in reality completely independent of each other, situated at immense distances and depths, but, being on the line of sight very near together, they appear to us collected on one plane. Nevertheless, there are probabilities in favour of the opinion which considers this sextuple star as an actual system, especially when we see that the movement belonging to the principal star is shared by the five others.

Another star in Orion, the twenty-third, is equally remarkable, being double, and instead of having its principal white and its small one blue, as in the generality of cases, it is the contrary that is noticed.

This is a great deal for one constellation ; but for this beautiful and ancient figure, about which Job sang three thousand years ago, I have a sympathy for which I cannot and will not defend myself. Between the Pleiades and the beautiful Sirius, it presents to me a magnificent celestial region, enriched with varied worlds, which makes one dream of distant life. Between ourselves, I read an astrological treatise of the middle ages : its title was 'Flamma Orionis.' Since that time this name is dear to me : I love it ! Now, you know what happiness it is to lovers to speak continually of the object of their devotions. Following its course, like the Sun, and the planets, and zodiacal constellations, the Moon sometimes passes near Orion. It then hides the stars over which its path conducts it. In speaking of Orion, the American poet, Longfellow, has pictured this occultation in bright colours:—

> ‘Sirius was rising in the east,
> And, slow ascending one by one,
> The kindling constellations shone.
> Begirt with many a blazing star,
> Stood the great giant Algebar,
> Orion, hunter of the beast!
> His sword hung gleaming by his side,
> And, on his arm, the lion’s hide
> Scattered across the midnight air
> The golden radiance of its hair.
> The moon was pallid, but not faint,
> And beautiful as some fair saint
> Serenely moving on her way
> In hours of trial and dismay,
> As if she heard the voice of God.
> Unharmed, with naked feet she trod
> Upon the hot and burning stars,
> As on the glowing coals and bars
> That were to prove her strength, and try
> Her holiness and her purity.
>
> ‘Thus moving on with silent pace,
> And triumph in her sweet, pale face,
> She reached the station of Orion.
> Aghast he stood, in strange alarm!
> And, suddenly, from his outstretched arm,
> Down fell the red skin of the Lion
> Into the river at his feet.
> His mighty club no longer beat
> The forehead of the Bull; but he
> Reeled as of yore beside the sea,
> When, blinded by Œnopion,
> He sought the blacksmith at his forge,
> And, climbing up the mountain-gorge,
> Fixed his blank eyes upon the Sun.’

In the fable, Orion, the handsomest man of his time, was of such high stature, that when he walked on the bottom of the sea, his head exceeded the height of the waves; which means that this constellation is half beneath the equator and half above.

I have forgotten to add, that the three oblique stars which form his belt have been named the Three Magi Kings, Jacob's staff, and that in France we simply distinguish them under the name of the Rake.

To the south-east of Orion, on the line of the Three Kings, shines the most magnificent of all stars, Sirius, or $\alpha$ of the constellation of the Great Dog. This star of the first magnitude marks the upper eastern angle of a great quadrilateral, whose base reaches the London horizon, and is adjacent to a triangle. The stars of the quadrilateral and the triangle are all of the second magnitude. This constellation rises in the evening, at the end of November, passes the meridian at the end of January, and sets at the end of March.

Sirius being the most brilliant star of the heavens, and astronomers daring to attempt operations relative to the study of the distances of stars, this attracted their attention. After long and minute study they succeeded in determining its distance; 1,375,000 times the distance of the Sun. To traverse the distance from the Earth to this star, light takes nearly twenty-two years. Hence, it follows that, when we see it, it is not the Sirius of to-day which is before our eyes but rather the Sirius of twenty-two years ago; the ray of light which reaches our eye now left Sirius during the year 1848.

The name we now give to $\alpha$ of the Great Dog formerly belonged to the whole constellation, and not a single Egyptian monument is found where this figure is indicated without its representing Sirius, a name derived from Osiris, the Sun. At the time the constellation was formed, the summer solstice happened when the Sun crossed Capricornus; the rising of Sirius announced to Egypt the time of the overflowing of the Nile, and like a faithful dog warned men to be on their guard. The *rôle* of Sirius did not stop here. The civil year of the Egyptians being exactly 365 days, and their kings swearing never to allow the intercalation of supplementary days, this year advanced a day every four years on the solar year, and again coincided with it at the end of 365 times four years—in 1460 years; but during this time the civil periods, agricultural labours, fêtes, and the different parts of the calendar, could not be fixed by unchangeable dates. They therefore chose a sign in the heavens which announced the period of the solstice; the rising of Sirius in the morning, which was then called Sothis, announced the desired epoch. The heliacal (solar) rising of this star only happened on the same day after 1461 years.

Since those ancient days, a movement of the Earth which slowly modifies the path of the Sun among the constellations, which is called 'the precession of the equinoxes,' has deprived Sirius of its faculty of predicting the inundation and the solstice; its heliacal rising happens in Egypt now on the 10th of August instead of the 20th of June. But at the beginning of our era, it took place in July, in the midst of the great heats and the diseases they engender. Hence, this constellation was accused of a malignant influence, as may be seen in Sophocles and a hundred other more modern authors; it gives fever to men and madness to dogs. The term dog-days is derived from this. In order to conciliate Sirius, they raised altars on which were sacrificed the quail and the goat. They dreaded the star of the south.

> 'Jam rapidus torrens sitientes Sirius Indos
> Ardebat.'—*Georgics*, iv. 425.

> 'Sirius ardor;
> Ille sitim morbosque ferens mortalibus ægris
> Nascitur, et lævo contristat lumine cœlum.'—*Æneid*, x. 273.

Sirius, or the Dog-star, was also called the Dog of Procris, wife of Cephalus, who pierced her with an arrow shot accidentally, as Ovid relates at great length. Jean-Baptiste

Rousseau, who sometimes liked to parade his astronomical knowledge, has not quite succeeded, in speaking in our time of the burning Sirius in an ode to the Abbé Chaulieu; it is charming nevertheless:

'Mais aujourd'hui qu'en nos plaines
Le Chien brûlant de Procris
De Flore aux douces haleines
Dessèche les dons chéris,

'Veux-tu d'un astre perfide
Risquer les âpres chaleurs,
Et, dans ton jardin aride,
Sécher ainsi que tes fleurs?'

Sirius has a long and good reputation as a dog. After all the services which he had rendered to the Egyptians, Jupiter charged him with the care of his dear Europa; after the carrying off, he passed through the hands of Minos, Procris, Cephalus, and Aurora. Well-known authors even think that, in spite of all that precedes, he was Cerberus, the dog with three heads; their opinion is supported by this coincidence, that the Great Dog guards at the equator the lower hemisphere of the Egyptians, in the same manner as Cerberus watched the region of Tartarus. It is seen that this dog claims a very ancient nobility. No heraldic title can boast of such antiquity.

The Little Dog, or Procyon, which we have already seen on our zodiacal maps, is above Sirius and below the twins, Castor and Pollux, to the east of Orion. No bright star distinguishes it, unless it be $\alpha$. From a mythological point of view, it shares with the Great Dog most of the fables attributed to the latter.

The Hydra is a long constellation which occupies that quarter of the horizon, under the Crab, Lion, and Virgin. The head, formed by four stars of the fourth magnitude, is to the left of Procyon, on a line drawn by this star and Betelgeuse. The western side of the great trapezium of the

Lion, like the line joining Castor and Pollux, is directed to $\alpha$, of the second magnitude: it is the heart of the Hydra. On the back of the Hydra, stars of the second order may be noticed, the Raven and the Cup. Being like a river in its meanderings, the Hydra has been regarded as an inhabitant of the Nile and its representative. As the ship Argo is not far from here, some have even gone so far as to explain by certain aspects the deluge of Deucalion, who escapes in a vessel, and who, forty days after, makes certain that the waters have retired by sending forth a raven.

Eridanus, the Whale, the Southern Fish, and the Centaur, are the only important constellations we still have to describe. They will be found in the order indicated, to the right of Orion. Eridanus is a river composed of a series of stars of the third and fourth magnitude, which descends and winds from Orion's left foot to Rigel, being lost under the horizon. After having followed long windings, invisible to us, it is terminated by a beautiful star of the first magnitude, $\alpha$ or Achernar. This was the river into which Phaëton, who awkwardly conducted the car of the Sun, fell: it was placed in heaven to console Apollo for the loss of his son.

> 'Nevertheless Phaëton, his hair on fire, falls from the height of heaven, and leaves behind him a long train of flame. Eridanus, who flows in distant parts of the country, and had seen the birth of this unfortunate prince, received him in his waves, and washed his face, which was covered with foam.'

Below the Ram, a star of the second magnitude is met with, which forms an equilateral triangle with the Ram and the Pleiades: this is $\alpha$, or the jawbone of the Whale; $\alpha$, $\mu$, $\xi$ and $\gamma$ form a parallelogram—this is the head. The base, $\alpha$, $\gamma$, is prolonged to a star of the third magnitude, $\delta$, and to a star of the Neck marked $o$. This star is one of the most curious in the heavens; it is called the Marvellous, Mira Ceti. It belongs to the class of variable stars. Sometimes it equals in brightness stars of the first order, at others it becomes completely invisible. Its variations have been watched since the end of the sixteenth century, and it has been noticed that the period of increase and decrease is in the mean 331 days, but always irregular, being sometimes 25 days behind or 25 days in advance. The study of these variable stars will present curious phenomena to us.

The Whale was sent by Neptune to devour Andromeda. I shall not return to the history of this poor princess.

Four stars of the third magnitude form the tail of this cetacean and descend towards Fomalhaut, or $\alpha$ of the Southern Fish, which receives water from Aquarius. This asterism rises very little above the horizon of London.

Lastly, the constellation of the Centaur is situated below Spica of the Virgin. The star $\theta$, of the second magnitude, and the star $\iota$, of the third, mark the head and shoulder: this is the only part of the figure which rises above the horizon of London. The Centaur contains the star nearest to the Earth, $\alpha$, of the first magnitude. It is also in this constellation that the beautiful regular nebula is found, which we have already admired, the globular cluster Omega of the Centaur. The feet of the latter touch the Southern Cross, formed of four stars of the second magnitude, always hidden below our horizon. A little further south is the south pole.

## V.

## THE NUMBER OF THE STARS—THEIR DISTANCES.

> ‘Il est pour la pensée une heure . . . une heure sainte
> Alors que s’enfuyant de la céleste enceinte,
> De l’absence du jour pour consoler les cieux,
> Le crépuscule aux monts prolonge ses adieux.
> On voit à l’horizon sa lueur incertaine,
> Comme les bords flottants d’une robe qui traîne,
> Balayer lentement le firmament obscur,
> Où les astres ternis revivent dans l’azur.
> Alors ces globes d’or, ces îles de lumière,
> Que cherche par instinct la rêveuse paupière,
> Jaillissent par milliers de l’ombre qui s’enfuit,
> Comme une poudre d’or sous les pas de la nuit.’
>
> Lamartine.

In order that the mind may be less confused in the midst of these thousands of sparkling points, it has been agreed from the highest antiquity to class the stars according to their apparent brightness, besides the divisions we have just mentioned. We have seen that the brightest stars have been called stars of the first order, or magnitude, although this term does not imply anything relative to the actual size or brightness of the stars; those which follow, still in the order of their apparent brightness, have been called stars of the second magnitude; then come those of the third, fourth, and fifth magnitude, according as they appear smaller; lastly, stars of the sixth magnitude are the last stars visible to the naked eye.

The stars of the first magnitude are eighteen in number. In reality, the eighteenth, that is to say, the least brilliant of the series, might as well be inscribed in the first rank of the stars of the second magnitude, and the first of this second series might, in the same way, be added to the stars of the first magnitude. There is nothing in the nature of these separations which necessitates our classification; but as we must stop at one star, and a series is to be made, it has been agreed to make the list of stars of the first magnitude as follows:—

*List of Stars of the First Magnitude in the order of their decreasing brightness.*

1. Sirius, or α of the Great Dog.
2. η of Argo (variable star).
3. Canopus, or α of the Vessel.
4. α of the Centaur.
5. Arcturus, or α of the Cowherd (Boötes).
6. Rigel, or β of Orion.
7. Capella, or α of Auriga.
8. Vega, or α of Lyra.
9. Procyon, or α of the Little Dog.
10. Betelgeuse, or α of Orion.
11. Achernar, or α of Eridan.
12. Aldebaran, or α of the Bull.
13. β of the Centaur.
14. α of the Cross.
15. Antares, or α of the Scorpion.
16. Ataïr, or α of the Eagle.
17. Spica, or α of the Virgin.
18. Fomalhaut, or α of the Southern Fish.

It is generally thought that the brightest are the nearest, and that the stars appear to us smaller the more distant they are from us. Hence it follows that the number of the stars must increase in the inverse ratio of each magnitude: that the stars which form the second series, for instance, being on a more distant, and consequently larger, visual circle than that of the first series, are more numerous: that the third series is richer than the second, and so on. This is precisely what is observed. The stars of the second magnitude number about 55; of the third, 170; of the fourth, 500, &c. The following is, indeed, an easy method of knowing approximately the number of stars of each order. It has been remarked that each class is generally three times more numerous than that which precedes it; so that by multiplying the number of stars which compose any series by three, we have nearly the number of those which compose the following series. By this calculation the number of the stars of the six first magnitudes—in other words, that of the whole of the stars visible to the naked eye—would give a total of about 6000. Generally it is thought that more may be seen; we think we can count them by myriads, by millions: in this as in everything else, we are always given to exaggeration! Yet, in fact, the number of stars visible to the naked eye, in both hemispheres does not exceed this figure, and even then there are few eyes good enough to see more than 4000 or 5000.

But here, when our feeble sight gives way, the telescope, that giant eye which increases from century to century, piercing the depths of the heavens, constantly discovers new stars. After the sixth magnitude the first glasses revealed the seventh. Then they reached the eighth, the ninth. It is thus that thousands have increased to tens of thousands, and that tens of thousands have become hundreds of thousands. More perfect instruments have cleared these distances, and have found stars of the tenth and eleventh magnitudes. From this period they began to count by millions. The number of the stars of the twelfth magnitude is 9,556,000; added to the eleven preceding magnitudes the total exceeds fourteen millions. By the aid of still greater magnifying power, these limits are again surpassed. At the present time, the total number of stars from the first to the thirteenth magnitude inclusive, is calculated at 43,000,000. The sky is truly transformed. In the field of the telescope, neither constellations nor divisions are distinguished; but a fine dust shines in the place where the eye, left to its own power, only sees darkness on which stand out two or three

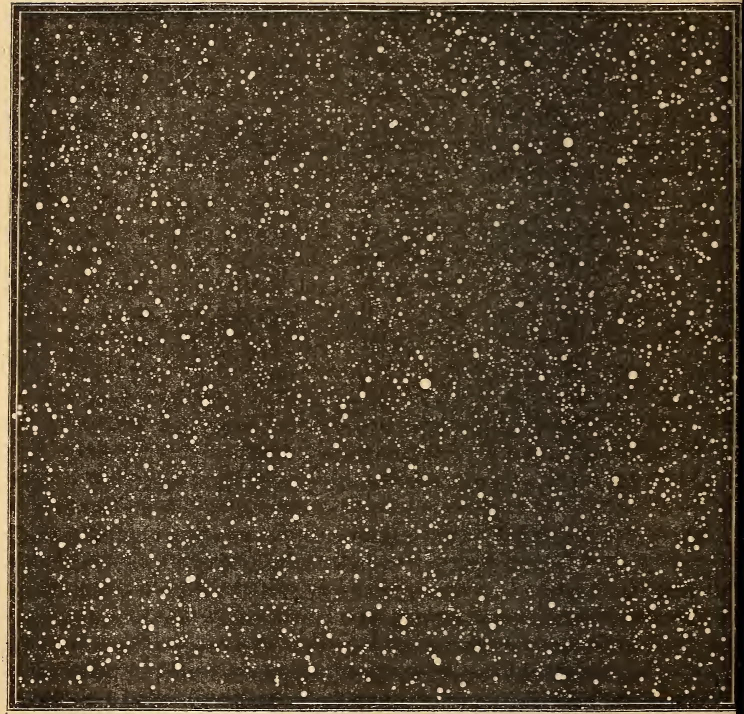

Fig. 21. A part of the constellation of the Swan, as seen through the telescope.

stars. In proportion as the wonderful discoveries in optics will increase the visual power, all regions of the sky will be covered with this fine golden sand; and a day will come when the astonished eye, raised towards these unknown depths, will be startled by the accumulation of stars which succeed each other in an endless manner, and will only discover a delicate tissue of light.

What is the extent occupied by these myriads of stars which succeed each other eternally in space? This question has always attracted the attention of astronomers as well as that of simple thinkers; but they were not able to commence any researches relative to its solution until lately, when delicate means have become accessible to us.

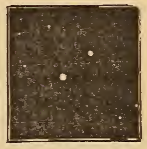

Fig. 22. The same seen with the naked eye.

The ancients did not form the slightest idea of the distance or nature of the heavenly bodies: they were thought to be emanations from the Earth, rising like the *ignes fatui* over marshy places. This would be a long and curious story, and, like that of all primitive ideas, but little in harmony with the grandeur of creation. To possess the power of measuring the distance of the nearest star, it is necessary to measure the thickness of a hair. A long time elapsed before this was accomplished. I shall give at the end of this chapter an idea of the method employed, in order to succeed in these exact determinations; we will first satisfy our curiosity, and learn at what distance the nearest stars are from us.

The nearest star is in the southern constellation of the Centaur; it is the star $\alpha$. According to the most recent researches, it is distant from us 211,300 times the distance from here to the Sun. A few years ago, it was believed to be further, but more exact determinations have definitely established that it is not beyond the distance just mentioned.

It is very difficult, if not impossible, to figure to oneself such distances, and to comprehend them, it is necessary for our mind to associate with the idea of space, the idea of time; to travel in some way along this line, and to estimate its length by time. For small distances, we do the same on the Earth. If, for example, it is said that it is 310 miles from Paris to Strasburg, we with difficulty figure this distance at first sight; but by associating the idea of the time necessary to pass through it with a given velocity, by learning that an express train going at the rate of 44 miles per hour, arrives there in seven hours, we represent to ourselves the road traversed. This method, useful for terrestrial distances, is necessary for celestial ones: we shall also measure space by time; only, instead of the velocity of a train, we shall take that of light, which travels at the rate of 136,000 miles per second.

Well, to traverse the distance which separates us from our neighbour *α* of the Centaur, our courier takes three years and eight months. If the mind wishes to follow it, it must not jump with the twinkling of an eye from the departure to the arrival, otherwise it would no longer have the slightest idea of the distance, it is necessary to represent to itself the direct path of the luminous ray, and to associate itself with this path, which it must imagine to travel 186,000 miles during the first second of route, dating from its departure; then 186,000 miles for the second second, which makes 372,000 miles; then again 186,000 miles during the third, and so on without stopping for three years and eight months.

If we give ourselves this trouble, it will enable us to understand the enormous value of the number; otherwise, as it exceeds every number which the mind is accustomed to use, it will not have any meaning and will remain uncomprehended.

Our nearest star is *α* of the Centaur. The one whose distance places it immediately after, is a star situated in another region of the sky, in the constellation of the Swan. This is our second nearest; which does not prevent it being nearly three times more distant from us than the first. The distances of ten stars have been calculated. The following are the nearest: The first column of numbers represents the number of radii of the terrestrial orbit (distance from the Earth to the Sun) which must be laid out in line, one from the other, to reach the star; the second column indicates the number of years light takes to traverse the distance:

| | | |
|---|---|---|
| α of the Centaur ... ... | 211,330 | 3 years 8 months. |
| α of the Swan ... ... ... | 550,920 | 9½ years. |
| Vega, α of Lyra ... ... | 1,330,700 | 21 ,, |
| Sirius, α of the Great Dog... | 1,375,000 | 22 ,, |
| α of the Great Bear ... ... | 1,550,800 | 25 ,, |
| Arcturus, α of Boötes ... | 1,622,800 | 26 ,, |
| Pole Star... ... ... ... | 3,078,600 | 50 ,, |
| The Goat, α of Auriga ... | 4,484,000 | 72 ,, |

These are the nearest stars. Most of the stars whose distances have been calculated are some of the brightest in the heavens, and are among those of the first and second magnitude. It may be asked if it be possible, by comparison, to determine the probable distance of the regions where the least magnitudes shine. This is a curious question, which Arago tried to solve and on which he reasoned as follows:

We take, for instance, from the foregoing list a mean star of the first magnitude, not Sirius, which exceeds all the others by its brilliancy, but Arcturus or Vega; we ask ourselves to what distance must this star be transported in order that it may diminish in apparent brightness to the fourth magnitude, and we see that it is necessary to transport it to a distance four times greater than its present distance; by withdrawing it to eight times the original distance, it would become from the fifth to the sixth order: in the mean, a star of the first magnitude transported to twelve times its actual distance, would still be visible to the naked eye, and its light would not fall below the sixth magnitude.

William Herschel tried to extend the scale of visibility which he had formed for the naked eye to telescopic observations. He prepared a series of telescopes of gradually increasing power, and for the subject of his observations he took the nebula of Perseus. There the eye could not distinguish any star. If there were any, they were necessarily more feeble than the stars of the first magnitude would be, transported to twelve times their actual distance; the small instrument showed a great number. Let us admit that, in this great number there are, which is probable, as bright stars as Arcturus, Vega, &c., these stars, in order to become just visible after their intensity was quadrupled, must be twice as far as the last stars visible to the naked eye, that is to say, twenty-four times further than Arcturus, Vega, &c.

The second instrument, which increased the light in the proportion of nine to one, and brought the objects three times nearer, discovered stars, the traces of which were not to be found in the first; the intensities of the stars were such as Arcturus, Vega, &c., would become at thirty-six times their distance.

By coming gradually to the telescope of nine feet focal length, the observer perceived stars of intensity similar to what the stars of the first magnitude would appear at 344 times the distance which now separates them from us.

The eighteen-foot telescope extended its power to 900 times the distance of the stars of the first magnitude; and it was evident that a more powerful telescope would have showed stars still more distant. To escape the numerical consequences that I am going to deduce from Herschel's results, it must be supposed that among the immense number of stars that each telescope of smaller power discovers, there does not exist one as brilliant as Arcturus or Vega of Lyra; in a word, it must be admitted that stars of the first magnitude only lie near our solar system. Such a supposition does not certainly deserve refutation.

There is no star of the first magnitude whose light reaches us in less than three years.

According to that, adds Arago, in conclusion, the light of the stars of different orders, in reality as large as Arcturus, Vega in Lyra, &c., arrives from such distances from the Earth that light could not pass through them,—

| | | |
|---|---|---|
| For stars of the second magnitude in less than . . | 6 | years. |
| „ fourth magnitude . . . . . . . | 12 | „ |
| „ sixth magnitude . . . . . . . | 36 | „ |
| For the last stars visible with the nine-foot telescope | 1042 | „ |
| For the last stars visible with the eighteen-foot telescope . . . . . . . . . . . . | 2700 | „ |

The luminous rays which reach us from the stars relate to us then, if we may so express it, the ancient history of these bodies. But by what power did man arrive at the knowledge of the distances of the nearest stars? In astronomy there are facts which surprise us by their grandeur, and which exceed the sphere of the habitual conceptions of man in such a way, that one is tempted to question them with doubt in spite of the affirmation of astronomers, and even to banish them to the rank of the deceitful pretensions with which science is sometimes surrounded, to impose on the vulgar. Of this number are the principal conquests of stellar astronomy, and particularly the determinations relative to the distance of the stars.

I shall endeavour to give an idea of the method which is employed to determine these distances, and by this explanation to remove the unfavourable idea still entertained by many of these perfectly established facts of modern astronomy.

A few instants' reflection will suffice to show, that if the Earth moves in space, during its annual course round the Sun, there must follow an apparent displacement of the other bodies in the sky. No one has looked from the window of a railway-carriage without seeing that the trees, houses, hills. and other objects which sprinkle the country, appear to move in an opposite direction to the path of the train, and that the nearest objects are those which appear to undergo the greatest displacement, whilst the most distant move more slowly, as far as the horizon, which remains nearly immovable. It must then follow from the movement of the Earth in space, that the stars, situated in the region of the heavens which the Earth leaves behind at a certain time of the year, will appear nearer together, whilst the stars which the Earth approaches will appear to get further apart. This effect will be necessarily less as the distances of the stars become greater. If it were possible to measure the displacement undergone by a star in consequence of the movement of the Earth, we should have the distance of this star. For let the ellipse in Fig. 23 be the curve followed by the Earth in its annual path round the Sun, and let S be the Sun, T S T′ a diameter of the terrestrial orbit, and T and T′ the position of the Earth at the two extremities of this diameter, that is to say, at six months' interval (as the Earth makes the entire passage in a year); lastly, let E be the star whose distance is to be measured.

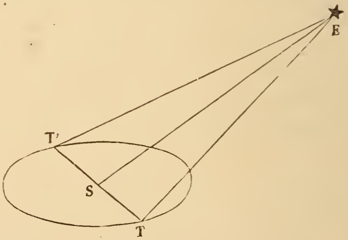

Fig 23. Measure of celestial distances.

When the Earth is situated at the point T, the angle S T E is measured, formed by the Sun, the Earth, and the star; when the Earth is at T′, the angle S T′ E is measured. It is known that in every triangle the total of the three angles is equal to two right angles, that is, to 180°; therefore, if the total of the two observed angles, S T E and S T′ E, is found, and this total is deducted from 180°, the value of the angle at E will be obtained, the angle subtended at the star by the diameter of the terrestrial orbit. And this value will be as exact as if we could have been transported to the star to measure it directly. The half of this angle, that is, the angle S E T, is what is called 'the annual parallax' of the star E. Thus the annual parallax of a star is the angle under which an observer placed on the star would see the radius of the terrestrial orbit.

By always taking corresponding observations at two diametrically opposite points of the Earth's orbit in the course of the year, a great number of measures of the annual parallax will be obtained in this manner. In our example, and in our figure, the star is situated near the pole of the ecliptic; the operation is the same, although rather more simple for the other positions of the heavens. In practice. the measures of the angles S T E, S T′ E, are obtained in an exact way, by comparing the successive positions of the star observed with that of a relatively fixed star which has no parallax. The great majority of stars are among the latter. Astronomical researches have proved that there is not a single star with its parallax equal to 1″. They are all below it. To form an idea of this value, it must be understood that the circumference of astronomical circles used in observation is divided into 360 parts called degrees, each degree into 60 minutes, each minute into 60 seconds. This value of a second is so small that a spider's thread, placed in the field of view of the telescope, entirely hides the portion of the celestial sphere where the apparent movements of the stars are effected, a portion at most equal to 1″.

The star which these observations have proved to be the nearest, is the star $\alpha$ of the Centaur; its parallax is equal to 97 hundredths of a second (0″·97). From the star $\alpha$ of the Centaur, the radius of the terrestrial orbit is then reduced to 0″·97. Now, in order that the length of any straight line seen be reduced as to appear only under the small angle of 1 second, it is necessary that this line be at a distance of 206,000 times its length, and in order to reduce it to 0″·97, it must be still further removed to 211,330 times its length. These are mathematical data. Therefore the distance from us of the star $\alpha$ of the Centaur is 211,330 times the radius of the terrestrial orbit, that is to say, 211,330 times 91 millions of miles.

This is the nearest star. Light travels for three years and eight months to come from it, to the Earth. The other near stars succeed each other, as we have seen, at greater distances.

From the preceding it will be seen that these results, however prodigious they may appear at first sight, are due to mathematical methods of great simplicity. All the difficulty in this sort of determination consists in the extremely minute, long, and laborious observation of the slight displacement of the star in the heavens.

All these stars, vast as our Sun, separated from each other by such distances, succeeding each other in an endless manner in the immensity of space, are in motion in the heavens. Nothing is stationary in the universe, there is not a single atom of matter in absolute repose. The formidable forces with which matter is animated universally regulate its action. These movements of the suns of space are imperceptible to our eyes, because they are performed at too great a distance; but they are more rapid than any velocity we can observe on the Earth; there are some stars which are carried away in space with a rapidity of fifty miles per second. To the eye which knew how to make abstraction of time as of space, the sky would be a moving swarm of stars.

## VI.

## VARIABLE STARS—TEMPORARY STARS—STARS SUDDENLY VISIBLE OR INVISIBLE.

'J'étais seul près des flots par une nuit d'étoiles.
Pas un nuage aux cieux, sur les mers pas de voiles.
Mes yeux plongeaient plus loin que le monde réel.
Et les bois et les monts, et toute la nature,
Semblaient interroger dans un confus murmure
    Les flots des mers, les feux du ciel.
Et les étoiles d'or, légions infinies,
A voix haute, à voix basse, avec mille harmonies,
Disaient en inclinant leurs couronnes de feu,
Et les flots bleus, que rien ne gouverne et n'arrête,
Disaient en recourbant l'écume de leur crête:
    —C'est le Seigneur, le Seigneur Dieu!'

VICTOR HUGO, *Orientales.*

Of all the wonders which the telescope has revealed in the fields of space, not one has perhaps more right to the astonishment of mortals than the existence of changing stars, periodically variable, whose light and colour undergo a periodicity of brightness; at least, observers have not been more surprised at any telescopic revelation. Stars which, far from remaining fixed in an unchangeable light, see their brightness periodically die away and again revive!—stars shining to-day with a splendid light will be invisible to-morrow, and after to-morrow again revived! The most daring imagination could scarcely invent such creatures; and now even, when their existence has been well proved, the mind can scarcely accustom itself to realise it.

These are stars whose light undergoes a periodical variation, bringing it by turns to its maximum and its minimum intensity. To figure to ourselves well in what this singular change consists, let us call to mind our Sun, and let us suppose it subjected to these variations. To-day it radiates the most transcendent flames, and pours down into the heated atmosphere floods of dazzling light; for some days it preserves this same intensity; but behold, the sky remaining clear as formerly, the light of the Sun gradually dies away from day to day: at the end of a week it has lost half its light; at the end of fifteen days it can be looked at steadfastly, and then it still fades, becomes pale and dull, only sending a wan light to the Earth. We tremble for its days, and we ask ourselves with the translator of Plutarch :—

> ‘Le Dieu qui du néant vient de tirer le monde
> Va-t-il le replonger dans une nuit profonde ?
> Le soleil, ce flambeau de la terre et des cieux,
> A-t-il vu pour jamais anéantir ses feux ?’

But it revives, and with it hope. The first progress in its extinguished light is noticed; it becomes whiter and more brilliant. The torch is relighted and increases from day to day; a week after its minimum intensity, it already sends forth a light and heat which bring to mind the solar focus. Its increase continues. And when a period equal to that of its decline has passed, the dazzling Sun will have regained all its power and grandeur. The Earth is inundated with the rays of its brilliant light and its fertilising heat. But it does not enjoy this splendour long, for already the Sun recommences its decreasing curve. And so on, continually. The nature of this new Sun is periodical while the virtue of our preceding one was to preserve a permanent light and heat.

It may be imagined that these variations of light astonish the observer who contemplates them in the field of the telescope. The periods are of all lengths. For some stars, the thirtieth of the Hydra of Hevelius, for instance, the period is more than 1 year, being 494 days. It varies between the fourth magnitude and complete disappearance. The star $\chi$ of the neck of the Swan, varies from the fifth to the eleventh magnitude in a period of 404 days. Another star of which we have already spoken in the chapter on the constellations, $o$ of the Whale, also called the Marvellous (Mira Ceti), varies in 334 days from the second magnitude to total disappearance. Other stars are regulated by more rapid variations. The star which passes most rapidly from its maximum to its minimum, is Algol in Medusa's Head, which we already know ($\beta$ of Perseus). For in 1 day, 10 hours, and 24 minutes, it has finished its decrease; in the same lapse of time it has reached its maximum: its period is only 2 days, 20 hours, 48 minutes. The star $\delta$ of Cepheus varies in a period of 5 days, 8 hours, and 37 minutes, from the third to the fifth magnitude. It will be seen that these variations are themselves very variable, and that there are suns which pass with strange rapidity from their greatest to their smallest light. What are the prodigious forces which regulate these gigantic changes? Science has not yet been able to determine this. Maupertuis said that variable stars were of the form of lenses, that they turned perpendicularly on themselves, and that they presented to us successively their edge and front. At the period when they presented the edge, their light was at the minimum; and at the time when they presented their entire front, it was at their maximum. But do lens-like suns exist? If the thing is possible, it is not proved. Not only are there stars whose light changes periodically, sometimes diminishing until they become completely invisible, although, in reality, they are not quite extinguished; but there are again others whose light is weakened never to be revived, and which for ever have disappeared from the sky. These are the extinguished stars of which the list is rather long. The astronomer, Ulugh-Beigh, stated, in the year 1437, that one star of Auriga, the eleventh of the Wolf, six stars, among which four of the third magnitude near the Southern Fish, all marked in the catalogues of Ptolemy and Abdurrahman-Suphi, were no longer visible in his time. In the seventeenth century, J. D. Cassini, and at the end of the eighteenth, W. Herschel, pointed out a great number of other stars which had completely disappeared. These were systems for which the hour of the end of the world had struck.

Speaking of the end of the world, this dread is awakened in the inhabitants of the Earth, not when stars disappear from the firmament, for this is mostly noticed by astronomers, but rather when a new body is suddenly lighted up in the heavens. Indeed there are stars which suddenly appear. In the same year as the massacre of Saint Bartholomew, on the 11th of November, 1572, a magnificent star of the first magnitude suddenly appeared in the constellation of Cassiopea, effacing by its brilliancy the most beautiful stars in the sky. It remained for eighteen months, and disappeared never to return.

Astrologers said that this appearance was the same as that to the Magi at the birth of Jesus Christ, and concluded from it that the last judgment was near. Thirty-two years later another new star appeared in the constellation of Serpentarius. From the day of its appearance, the 10th of October, 1604, according to Arago, it was white; it surpassed stars of the first magnitude in brightness, also Mars, Jupiter, and Saturn, which were near it. Many compared it to Venus. Those who had seen the star in 1572 found that the new one exceeded it in brightness. It did not appear to become fainter in the second half of the month of October; on the 9th of November, the twilight which effaced Jupiter did not prevent this star from being visible. On the 16th of November Kepler perceived it for the last time, but at Turin, when it reappeared in the east, at the end of December and at the beginning of January, its light was fainter; it certainly surpassed Antares, but was not equal to Arcturus. On the 20th March, 1605, it was smaller in appearance than Saturn, but it exceeded in brightness the stars of the third magnitude in Ophiuchus. On the 21st of April it seemed equal to the shining star of the third magnitude in the knee of Ophiuchus. It diminished imperceptibly; on the 8th of October it was still seen, but with difficulty, on account of the twilight. In March, 1606, it had become completely invisible.

These appearances, like all extraordinary phenomena, excited terror and awakened ideas, not to be stifled, of the conflagration of the world, the fall of the stars, and the end of time. One of the most memorable predictions is that in 1588, announced in emphatic Latin verse, of which the following is a translation :—

'After one thousand five hundred years, dating from the conception of the Virgin, this eighty-eighth year will be strange and full of dread ; it will bring with it sad destinies. If, in this terrible year, the perverse world does not fall into dust, if the earth and seas are not annihilated, all the empires of the world will be overthrown, and affliction will oppress the human race.'

This prediction was later renewed in favour or disfavour of the seventeenth century, and the *Mercure de France* announced the greatest revolutions for the year 1788. It then passed for having been found in the tomb of Regiomontanus. Authors did not think how right they were to describe this memorable epoch under the title of revolution.

But while considering these predictions, the list of which would be longer than at first imagined, I cannot help relating the curious mystifications worked in 1524 by the German Astrologer Stoffler. According to him, on the 20th of February of that year, the conjunction of the planets in the Fishes must produce a universal deluge. Astrologers gave faith to it like the common herd: the sinister news soon traversed the world, and they prepared themselves to see the universe pass from time into eternity. 'All the provinces of Gaul,' says an author of that period, 'were in strange fright and doubt of a universal inundation, and such that our fathers had not seen, or was known by historians or others, by means of which men and women were in great fear. And many removed from their low dwelling-places, and found higher spots, made provision of meal and other matters, and had processions and general and public prayers, that it might please God to have pity on His people.'

Fear seized on a great many minds. Those who lived near the sea or rivers left their abodes, and sold, at immense losses, doubtless to unbelievers, their properties and goods. At Toulouse, another Noah constructed a ship to serve as an ark to his family and friends,—and, probably, also to a few couples of animals. This was not the only case. According to the account of the historian, Bodin, 'There were many infidels who made arks to save themselves, although God's promise and oath, never again to drown man by a deluge, was preached to them.' Many and many a time the prediction was given out, and, sad to say, it always found the same number of believers, although each time the event gave it a positive denial. In 1584, the fear caused by an announcement of this kind was so great that the churches were unable to contain those who sought refuge in them; a great number made their wills without reflecting that it was useless if all the world was to perish; and others gave their goods to the priests, in the hope that their prayers would delay this day of judgment. I believe that as long as the world remains it will fear its dissolution.

These singular stars which are suddenly lighted up in the heavens, to be extinguished soon after—these variable suns which pass through all degrees of light, and seem, like Castor and Pollux, to have received as a destiny an everlasting transitory movement from life to death and death to life, little suspect the terrors which they so innocently cause to spring up among men. What unknown power presides over these variations of light and heat? What influence on the planetary worlds which circulate round these bodies is of so strange a nature? What thought regulates these movements, and what hand constructs beings born to live in harmony with such systems? What distance separates terrestrial nature, where years follow each other by a permanent law, and bring back successively the same phenomena, from those worlds where such prodigious variations take place? The mind is astonished with these questions and cannot answer them. Towards the end of the night, when sunrise began to cause the stars to fade, the English poet Kirke White expressed his astonishment in these terms:—

'Ye many twinkling stars, who yet do hold
Your brilliant places in the sable vault
Of night's dominions!—planets, and central orbs
Of other systems;—big as the burning Sun
Which lights this nether globe,—yet to our eye
Small as the glow-worm's lamp!—to you I raise
My lowly orisons, while, all-bewildered,
My vision strays o'er your ethereal hosts;
Too vast, too boundless, for our narrow minds,
Warped with low prejudices, to unfold,
And sagely comprehend; thence, higher soaring,
Through ye I raise my solemn thoughts to Him,
The mighty Founder of this wondrous maze,
The great Creator!—Him, who now sublime,
Wrapt in the solitary amplitude
Of boundless space, above the rolling spheres,
Sits on his silent throne, and meditates.

'Thou, proud man, look upon yon starry vault,
Survey the countless gems which richly stud
The Night's imperial chariot;—telescopes
Will show thee myriads, more innumerable
Than the sea sand; each of those little lamps
To the great source of light, the central sun,
Round which some other mighty sisterhoods
Of planets travel, every planet stock'd
With living beings impotent as thee.
Now, proud man! now, where is thy greatness fled?
What art thou in the scale of universes?
Less, less than nothing! Yet of thee the God
Who built this wondrous frame of worlds is careful,
As well as of the mendicant who begs
The leavings of thy table.'

## VII.

## DISTANT UNIVERSES—DOUBLE, MULTIPLE, AND COLOURED SUNS.

‘Par delà l’infini des cieux,
Je vis encore une étendue
Où des soleils mystérieux,
Qui se cachent à notre vue,
Illuminent d’autres mortels.
Là notre terre est inconnue,
Là sont d’immenses archipels
Dont les humains, sans se connaître,
Adorent tous le même Maître,
Chacun sur différents autels.’

THE wonders we have just reviewed become insignificant before those which we approach. Here, what we call natural is quite overthrown. Our observation, ideas formed by experience, classification, and judgment in that which concerns the works of nature, have no longer the least application. We are really in another world, strange, improbable, and unnatural to us. Life, the forces which sustain it, light, heat, electricity, the periods of days and nights, seasons, years, the visible and invisible world, all are transformed. Here we are on the surface of celestial globes, illuminated by many suns, of all magnitudes, lights, colours, and by moons with many-coloured discs. Nothing like it has been seen on the earth: are these truly our worlds?—are these not other universes?

Let us, then, sum up the studies we have made on the nature of these worlds in our panorama,* and let us observe the essential types of the astonishing diversity which contrasts them from ours.

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* See *Annuaire du Cosmos for the year* 1865.

The white light of our Sun pours its dazzling rays from the azure height, and, thanks to the transparent atmosphere in which a thousand reflections form a real reservoir of light, all the objects which clothe or people the surface of the globe are enveloped in this light. Nevertheless, this white light is not simple. It contains in its rays all possible colours; and bodies, instead of appearing to us clothed with a uniform whiteness, absorb certain colours of this complex ray and reflect others; it is this reflection which constitutes the coloration of these bodies. This depends, then, on the molecular agency of the reflecting surface, on its power of receiving certain rays of the spectrum and of repelling others. But all these colours constitute the original white—the one source of these various appearances.

It is now well to remember that this theory, applicable to the organic world, receives still more considerable importance when we consider the mode of coloration of organic substances. The beauty of plants, the diversity of the meadows, the gold of the fields, the whiteness of the lily, the scarlet, orange, azure, and the charming shades which form the richness of the flowers, the brilliancy of plumage of little tropical birds, the snowlike doves, the yellow fur of the desert lion, like the radiancy of flaxen hair: it is to the white light of our Sun that we must go for the explanation of these visible beauties—in him resides the source of the infinite shades which decorate the forms of nature.

Now let us, for an instant, suppose that, instead of a white sun, the source of all the light which inundates us, we had a dark blue sun. What a change is soon worked in nature! The clouds lose their silvery whiteness and gold from their flakes, and spreading a darker vault under the heavens, all nature is covered with a coloured penumbra, while the beautiful stars remain in the noon-day sky; the flowers lose the light of their brilliant dress; the fields succeed each other in the mist as far as the invisible horizon; a new day shines under the heavens.

The carnation of fresh cheeks loses its budding bloom, faces appear to be aged, and astonished humanity asks for the explanation of such a strange phenomenon. We know the rudiments of things so little and we hold so much to appearances, that the whole universe seems to us renewed by this slight modification of solar light.

How would it be if, instead of an indigo sun, following its apparent course with regularity, making the years and days certain by its own rule, a second sun suddenly arrived in addition to it, a scarlet sun continually disputing the empire of the world of colours with its partner? Imagine at noon, at the moment when our blue sun spreads that shadowy light over nature which we have just described, the conflagration of a resplendent orb kindling its flames in the east. Greenish silhouettes suddenly rise through the diffused light, and opposite each object a dark shadow cuts the blue light which spreads over the world. Later the red sun rises as the other sinks, and the objects are coloured, to the east with the red rays, to the west with the blue. Later still, as a fresh mid-day lights up the Earth, the first sun vanishes, and from that time nature is clothed with a scarlet fire. If we pass to the night, scarcely have the last rays of the purple sun faded away in the west, like distant Bengal fires, than a new sunrise appears opposite the azured glimmer of the cyclops with the blue eye.

Is it possible for the imagination of poets or the caprice of painters to create on the palette of fancy a more daring world of light than this one? The foolish hand of chimera, throwing on its impressible sheet the odd colours of its will, can it erect at hazard a more wonderful edifice than this? Hegel said that 'all which is real is rational,' and 'all which is rational is real.' Yet this bold thought does not express the whole truth. There are many things which do not appear to us rational, and which, nevertheless, exist in reality in the numberless creations of space which surround us.

What we have just said respecting an Earth lighted up by two suns of different colours, one being dark blue and the other scarlet, is not imaginary. In a beautiful calm, clear night take your glass and look at Perseus, this hero walking in the midst of the Milky Way, holding Medusa's head in his hand; look at the star η, this is a world such as that of which we have just spoken. The large star is of a beautiful red, the other of a dark blue. At what distance is this strange system situated? no one can tell. It can only be stated that, at the rate of 186,000 miles per second, light takes more than a hundred years to reach us from thence.

But this is not the only system of the kind. That of γ of Ophiuchus resembles it so much that they may be easily mistaken one for the other (at such a distance, it would indeed be excusable) only in the system of Ophiuchus the blue sun is not so dark as in the others. One star of the Dragon very much resembles the preceding, but then the large sun is of a deeper red, its small one blueish; another again, η Argo, has its large sun blue and its less brilliant one dark red.

Thus we have our imaginary world realised in many parts of space. And perhaps there are human eyes who thus contemplate those wonders each day. Who knows? —and the thing is very probable—perhaps they pay no attention to it, and from their cradle accustomed like us to the same sight, they do not appreciate the picturesque value of their abode. Thus are men constituted. The novel and unexpected alone affect them; as to the natural, this seems but an eternal, necessary, and fortuitous state of blind nature, which does not deserve the trouble of being observed. If the people came thence to us, though acknowledging the simplicity of our little universe, they would not fail to observe it with surprise, and be astonished at our indifference.

It was doubtless, after having dreamt of these strange and distant worlds that Victor Hugo wrote the following stanzas :—

'S'il nous était donné de faire
Ce voyage démesuré,
Et de voler de sphère en sphère
A ce grand soleil ignoré ;
Si, par un archange qui l'aime,
L'homme aveugle, frémissant, blême,
Dans les profondeurs du problème,
Vivant, pouvait être introduit ;
Si nous pouvions fuir notre centre,
Et, forçant l'ombre où Dieu seul entre,
Aller voir de près dans leur antre
Ces énormités de la nuit ;

'Ce qui t'apparaîtrait te ferait trembler, ange !
Rien, pas de vision, pas de songe insensé,
Qui ne fût dépassé par ce spectacle étrange ;
Monde infernal, et d'un tel mystère tissé,
Que son rayon fondrait nos chairs, cire vivante,
Et qu'il ne resterait de nous dans l'épouvante
Qu'un regard ébloui sous un front hérissé.
Tu verrais !—un soleil, autour de lui des mondes,
Centres eux-même, ayant des lunes autour d'eux ;
Lá, des formillement de sphères vagabondes ;
*Là des globes jumeaux qui tournent deux-à-deux.*'

The suns which constitute these multiple systems differ therefore from ours by their coloration; and, among the whole of the bodies, a fresh variety again manifests itself. Coloured binary systems are not composed solely of the red and blue suns to which we have just alluded; the means have not been at fault, it is the same here as in the universality of the productions of nature ; it is from an inexhaustible source that it has drawn the richness and sumptuousness with which it has decorated its works.

For instance, the following is the beautiful system of $\gamma$ of Andromeda. The large central sun is orange, the small one which gravitates near it is emerald green.* What follows from the union of these two colours? The orange and the emerald? Is not this an assortment full of youth, if this metaphor be permitted? A large and magnificent orange sun in the midst of the heavens; then a bright emerald which gracefully joins its green radiations to the gold.

Then again, in Hercules, we have two suns, red and green; in Berenice's Hair, one pale red, the other a clear green; in Cassiopea, a red and a green sun: a fresh series of soft and charming shades.

Let us change the prospect; to do this, it is only necessary to consider other systems. There is more variety amongst them than in all the changes which an optician can produce on the screen of a magic-lantern. Certain planetary universes lighted up by two suns have all the series of colours included under blue, and the brilliant shades of gold and purple which throw so much vivacity on this world are there unknown. It is in this category that are placed certain systems situated in the constellations of Andromeda, the Serpent, Ophiuchus, Berenice's Hair, &c. Others, again, only know red suns, like a double star of the Lion for instance. Some other systems are devoted to the blue and yellow, or at least are lighted up by a blue sun and a yellow sun, which only give them a limited series of shades comprised in the combinations of these primitive colours; such are the systems of the Whale, of Eridanus, one of which is straw colour and the other blue, the Giraffe, Orion, Unicorn, the Twins, Boötes, the large yellow and the greenish-blue of the Swan; the small one is of an intense blue. We have, on the other hand, assortments of red and green; as is seen in Cassiopea, Berenice's Hair, and Hercules.

Other stellar systems are nearer ours, in the sense that one of the suns which illuminates them has, like ours, a white light, the source of all colours, whilst its neighbour throws a simple radiation on everything. For instance, in the worlds which revolve round the great sun $\alpha$ of the Ram; the large sun is white, but we constantly see in the heavens another smaller sun, whose blue reflection covers the objects exposed to its rays, as with a veil. The 26th of the Whale is in the same condition, and it is the same with a great number among the brightest stars. Such is the star $\chi$ in the Swan's neck, which is besides one of the most remarkable of the variable stars, for in a period of 404 days the large white sun diminishes from the fifth to the eleventh magnitude and returns to its primitive state. To the worlds which gravitate round the principal sun in these binary systems, the original white light appears to give rise to the infinite varieties which we observe on the Earth, with the addition of a blue light constantly coming from the other sun; but to the planets which gravitate round this one, it is the blue coloration which predominates, whilst the action of the more distant white sun is only secondary.

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* Our author might have added that this green star is double, and is built up of one blue and one yellow star.—Tr.

In the same way as there are white suns, accompanied with blue suns, some are also accompanied with red or yellow suns. But I must not dwell on this enumeration if I wish to review the whole host of the sky.

What a variety of light with two suns, one red and the other green, or one yellow and the other blue, must be experienced on a planet which revolves round one or the other; and what charming contrasts, and what magnificent alternations must arise from a red day and a green day, succeeded in turn with a white day and with darkness! What nature is there! What unimaginable beauty clothes with unknown splendour these distant lands scattered in endless space?

If like our Moon which gravitates round the globe, or like those of Jupiter and Saturn, which unite their mirrors on the dark hemisphere of these worlds, the invisible planets which are there poised are surrounded with satellites which constantly accompany them; what is the aspect of these moons, lighted by many suns? That moon which rises from the luminous mountains is divided into differently-coloured quarters, one red, another blue; this other only presents an increasing yellow; that one is at its full, it is green, and appears suspended in the heavens like an immense fruit. A ruby moon, an emerald moon, an opal moon, what heavenly jewellery! O night of the Earth, which modestly silvers our solitary moon, thou art very beautiful when the calm and pensive mind contemplates thee! But what art thou beside nights illuminated by these wonderful moons?

And what are eclipses of the Sun on these worlds? Multiply suns and multiply moons, to what endless changes must your mutually-eclipsed lights give rise? The blue sun and the yellow sun stand near each other; their combined light produces green on the surfaces illuminated by both of them, yellow or blue on those which receive only one light. Soon the yellow approaches the blue; already it enters on its disc and the green spread over the world fades, and fades, until the moment when it expires, melted into the gold which pours in space its beautifying rays. A total eclipse colours the world with yellow. An annular eclipse presents a blue ring round a gold piece. By degrees, imperceptibly, the green revives and holds its empire.

Let us add to this phenomenon another which would be produced if a moon came over the beautiful middle of this golden eclipse, to cover the yellow sun itself and to plunge the world in obscurity, then follow the relations existing between its movement and that of the Sun, continuing to hide it after its departure from the blue disc and then to leave nature again fallen under the veil of a new azure. Let us again add,—but no, this is Nature's inexhaustible treasure; however much we take from it it will not be impoverished.

I will terminate these descriptions by a graceful poem, 'The Song of the Stars,' by the American poet Bryant. These stanzas are in their proper place, after the harmonies of light and charming colorations that we have just observed in the world of these distant stars :—

‘When the radiant morn of creation broke,
And the world in the smile of God awoke,
And the empty realms of darkness and death
Were moved through their depths by his mighty breath,
And orbs of beauty, and spheres of flame,
From the void abyss by myriads came,
In the joy of youth, as they darted away,
Through the widening wastes of space to play ;
Their silver voices in chorus rang,
And this was the song the bright ones sang :—

‘“Away ! away ! through the wide, wide sky,
The fair blue fields that before us lie ;
Each sun with the worlds that round us roll,
Each planet poised on her turning pole,
With her isles of green, and her clouds of white,
And her waters that lie like fluid light.

‘“For the source of glory uncovers His face,
And the brightness o'erflows unbounded space ;
And we drink as we go, the luminous tides
In our ruddy air, and our blooming sides ;
Lo, yonder the living splendours play !
Away, on our joyous path, away !

‘“Look ! look through our glittering ranks afar,
As in infinite azure, star after star
May brighten and bloom as they swiftly pass !
The verdure runs o'er each rolling mass !
The path of the gentle winds is seen,
And the small waves dance, and the young woods lean.

And see where the brighter day-beams pour,
How the rainbows hang in the sunny shower,
And the morn and the eve, with their pomp of hues,
Shift o'er the bright planets and shed their dews,
And 'twixt them both o'er the teeming ground,
With her shadowy cone, the night goes round.

'"Away! away!—In our blossoming towers,
In the soft air wrapping these spheres of ours,
In the seas and fountains that shine with morn,
See love is brooding, and life is born,
And breathing myriads are breaking from night,
To rejoice like us, in motion and light."

'Glide on in your beauty, ye youthful spheres!
So weave the dance that measures the years,
Glide on in the glory and gladness sent
To the farthest wall of the firmament,
The boundless visible smile of Him,
To the veil of whose brow your lamps are dim.'

# BOOK III.

## THE SUN'S DOMAIN.

# I.

## THE PLANETARY SYSTEM.

‘Dans le centre éclatant de ces orbes immenses
Qui n’ont pu nous cacher leur marche et leurs distances
Luit cet astre du jour, par Dieu même allumé,
Qui tourne autour de soi sur son axe enflammé :
De lui partent sans fin des torrents de lumière ;
Il donne en se montrant la vie à la matière ;
Et dispense les jours, les saisons et les ans,
A des mondes divers, autour de lui flottants.
Ces astres, asservis à la loi qui les presse,
S’attirent dans leur course et s’évitent sans cesse,
Se servent l’un à l’autre et de règle et d’appui,
Se prêtent les clartés qu’ils reçoivent de lui.
Au delà de leurs cours, et loin dans cet espace
Où la matière nage et que Dieu seul embrasse
Sont des soleils sans nombre et des mondes sans fin . . . .
Par delà tous ces cieux le Dieux des cieux réside.’
VOLTAIRE.

We will now descend from the stars as a whole to a particular one; from the general contemplation of our universe to the study of a limited region. After having embraced the extent of this vast and imposing domain explored by science, we shall concentrate our attention on a single point, like the observer who, wishing to give an account of the position of a house in a landscape, after having first examined the neighbourhood and places which surround it, concentrates his attention on the house itself. If the immensity of the numbers or the infinity of this expanse no longer present themselves in this new contemplation in a way to astonish our mind and confuse our faculties, the inalienable characteristics which universally distinguish the works of nature, will reveal to us more sensible and touching beauties, not less worthy of our attention. In nature's perfect work, the most modest of its creations present the Divine sign of their origin, and the most simple unfold a hidden splendour, not less wonderful than the most brilliant manifestations. Thus the splendid coruscations of the Aurora Borealis, which the gigantic shadow of an invisible hand lifts up on the icy pole, are produced in a brighter colour, and in a still more charming aspect, on the perfumed corolla of each little flower.

Nevertheless, it must not be imagined that we are going to descend to small objects. They have still colossal forms, at the sight of which the imagination is confused. We are going to occupy ourselves with the system of worlds to which the Earth belongs, and which is commanded by the Sun. Perhaps even we shall feel greater interest in studying things which relate to us more closely, than in those whose distance makes us strangers to their most precious riches.

Here we are at length, arrived nearly at our own abode in space. Descended from the heights of sidereal creation, after having commenced our study with the imaginary circumference which the limits of our sight extended by instruments describe round the point we inhabit, we have gradually approached the centre. Is not the observation of our celestial position more interesting than that of the other cities of space?

The Sun which lights us is one of the stars of the Milky Way, a unit lost in the millions which constitute this nebula. But it is no longer as a star that we must now examine it, but as the centre of a system of worlds grouped around it. Around this luminous body are collected opaque bodies, dark in themselves, and which receive their light and heat from it. These dark bodies are called Planets. To render the study of them more easy, and to help to distinguish them better, they may first be divided into two very distinct groups. The first, near the Sun, is formed of four planets, of small dimensions relatively to those of the second group. These four planets are, in the order of their distances from the Sun, Mercury, Venus, the Earth, and Mars.

The second group, more distant from the Sun, is also formed of four planets ; but they are large as compared with the preceding. These four worlds are in the order of their distances from the radiant body, Jupiter, Saturn, Uranus, and Neptune. These bodies are so bulky that the first four united into one would not form one globe of the size of the smallest amongst them.

Now, between these two distinct groups, there is a third, formed of a considerable number of small bodies, of which 109 are already known. These little planets occupy the space which extends from the first to the second group. Compared with the other globes of the system, they are very small bodies indeed, for most of them measure less than a hundred leagues in diameter, and in some even the diameter is only a few miles.

These planets, great and small, are the principal members of the family. We must now add to them some secondary members, satellites which belong to some of them, and are grouped round the planets, like these are round the Sun. Of these satellites, the Earth possesses one, the Moon ; Jupiter four, Saturn eight, Uranus four, and Neptune, probably two.

At what distances are these planetary bodies situated round the central body ? Mercury, the nearest is 35,000,000 miles from the Sun ; Venus, which comes next, at 66,000,000 ; the Earth, 91,000,000 ; and Mars, 139,000,000. The group of the small planets occupies a more distant zone, in the mean 266,000,000 miles from the central orb. Then come the four large planets : Jupiter, nearly 476,000,000 miles ; Saturn, 872,000,000 ; Uranus, 1,754,000,000 ; and Neptune, the last, 2,746,000,000 miles. All revolve round the Sun at the respective distances which have been stated, and revolve in more or less time, according as they are more or less distant from that body. The nearest having a shorter path to travel, and being more strongly attracted revolve more rapidly; the more distant travel slowly, compared to the preceding. The Earth takes 365 days to accomplish its revolution; Mercury only 88, whilst Neptune takes more than 164 years. These movements are regulated by an admirable and very simple law discovered by the illustrious Kepler, after thirty years of study. Expressed in astronomical terms, this law is thus announced: 'The squares of the time of the revolutions of the planets are as the cubes of their distances from the Sun.' In other words, by multiplying the number which represents the distance of a planet from the Sun thrice into itself, we have double the time of its revolution multiplied by itself. A little attention shows how simple this formidable law, which directs all the celestial movements in space, is. Thus, for instance, Jupiter is five times further from the Sun than the Earth. I multiply this number three times by itself, 5 × 5 × 5 = 125. Well, this number 125 is precisely double the time of the revolution of Jupiter, multiplied by itself. It is the same for all planets, satellites, and celestial bodies. I must add, for the use of those who wish to go further into astronomy, that these bearings are not rigorously exact, and that if they were, the system of the world would be soon overthrown.

These movements, the formula of which was discovered by Kepler, are caused by attraction or universal gravitation, this law having been discovered by Newton. All bodies in nature attract each other; the Sun attracts the Earth, the Earth attracts the Moon, and in the infinitely small, as in the infinitely great, the elementary molecules are seen to attract each other by the law of affinity, and to constitute visible matter, which is only an assemblage of atoms in juxtaposition. It is in virtue of this universal force that the worlds launched in space describe a curve round the Sun; from this rapidly travelled curve would follow a force which, like that with which a stone is animated when it starts from a sling, would throw the planets out of their orbits, if the attraction of the Sun did not hold them captive. It is, indeed, attraction which rules the world, as Eugène Nus has sung:—

> 'La loi d'amour est souveraine :
> Partout son doux verbe est écrit.
> Elle féconde, unit, entraîne,
> La matière comme l'esprit.
> La terre s'échauffe à vos flammes :
> Les cieux modulent vos accords.
> Amour, attraction des âmes,
> Attraction, amour des corps !'

To complete this sketch of the Empire of the Sun, we must add to the preceding, certain bodies which, without departing from his kingdom, are always journeying. From time to time they pay a visit to the capital, then return to the provinces, at every imaginable distance. These are comets, wandering beings, if ever there were any, indefatigable travellers, but which the powerful attraction of the solar body always retains in the limits of his domain.

Such is the little group of worlds of which our Sun is the sovereign.

Imagine a magnificent vessel, the *Great Eastern* for example, sailing in the open sea. Around it move a quantity of little boats, which are insignificant in comparison, and around some of these boats children's little boats, like those we see in the ponds in our squares. The boats placed at different distances move round the large vessel, and the toy-boats revolve round these boats. Lastly, a quantity of canoes alternately recede from and approach the large vessel, moving in ellipses.

This fleet of various small vessels is not immovable on the ocean ; and this is the most wonderful point. Besides all the circular movements of which I have just spoken, we must see the collective movement of the fleet, carried away on the liquid plain by the master-vessel. Fixed in the middle of the boats which revolve round it, the brilliant great ship sails on the ocean, drawing with it all its little satellites without their perceiving it, occupied as they are in faithfully revolving round the centre. So the Sun which it represents sails in space, drawing with it the Earth, Moon, planets, comets, and all its system. Where is it going? Towards what point are we all directed? Which is the point in space which sees our great fleet advancing towards it?

> 'Allons-nous sur des bords de silence et de deuil,
> Echouant dans la nuit sur quelque vaste écueil,
> Semer l'immensité des débris du naufrage?
> Ou, conduits par la main sur un brillant rivage,
> Et sur l'ancre éternelle á jamais affermis,
> Dans un golfe du ciel aborder endormis?'

It would be difficult for me to tell you if we are going to strike against a rock or to cast anchor in a gulf; I rather believe that we shall continue our path indefinitely; describing a gigantic orbit in the heavens. We are actually approaching an imposing constellation, the constellation of Hercules, situated between Lyra and Boötes. One day a small star will be seen to arrive in this constellation, between the stars $\mu$ and $\pi$ at a quarter of the distance from the second to the first. At this period the general aspect of the constellation will begin to change to us, seeing that the stars which we approach will get further from each other, as those which we leave behind will draw nearer together, and those on each side of us seem to fall back; but this period is so distant from us that the best eyes cannot reach it. It is true the Sun carries us away with a velocity of about two leagues per second, but there is such a distance between each star that this progress is almost insignificant. It must be remembered that there are stars whose movement is still more rapid.

Such is the aspect under which it is proper to comprehend the Sun in passing from its *rôle* of star to that of the head of a system. Now this last *rôle* will be the only one that we shall study. The stars being suns, it is more than probable, that to study and completely understand their history, they must also be considered under the same aspect, and be equally surrounded by their respective families; but these families are unknown to us, and man's mind is so constituted that it is difficult for him to entirely comprehend the sphere of known things, and he would be easily lost did he try to go beyond. Moreover, we always preserve, whatever we do, a little background of egotism, and we gladly reserve our attention for persons or things which touch us nearest. We have now passed definitely from sidereal to planetary astronomy.

# II.

## THE SUN.

'And see—the Sun himself!—on wings
Of glory, up the east he springs.
Angel of light! who from the time
Those heavens began their march sublime,
Has first of all the starry choirs
Trod in his Maker's steps of fire!

'Blest power of sunshine! genial day,
What balm, what life is in thy ray!
To feel thee is such real bliss,
That had the world no joy but this,
To sit in sunshine calm and sweet,—
It were a world too exquisite
For man to leave it for the gloom—
The deep, cold shadow of the tomb!'
MOORE'S *Lalla Rookh.*

'THE resplendent body which shines over our heads occupies the centre of the group of worlds to which the Earth belongs. Our planetary system owes its existence and life to it. It is truly the heart of this gigantic organism, as expressed in olden times by a happy metaphor of Theon of Smyrna, and its reviving pulsations sustain its long existence. Placed in the midst of a family as father, over which it ceaselessly has watched from unknown ages when the worlds left their cradles, it governs and directs, both in the maintenance of its interior economy, and in the individual *rôle* which it fills amidst the universality of the sidereal creation. Under the impulses of the forces which emanate from it or of which it is the pivot, the Earth and our companions, the planets gravitate round it, imbibing in their eternal courses, the elements of light, heat, and magnetism which constantly renew the activity of their life. This magnificent body is, at the same time, their support in space, the fire which warms them, the lamp which lights them, and the fertile source which pours out on them the treasures of existence. It is he who permits the Earth to float in the Heavens, held by the invisible network of the planetary attractions; it is he who guides it in its way and distributes to it years, seasons, and days. It is he who prepares a new clothing for the sphere yet frozen in the nakedness of winter, and who invests it with a luxuriant dress when it inclines its pole covered with snows towards him; it is he who gilds the harvests in the plains and ripens the heavy grape on the warm hills. It is this glorious body which, in the morning, spreads the splendour of the day over the transparent atmosphere, or rises from the sleeping ocean, which he will transform into charitable dew for the thirsty plains; it is he who forms the winds in the air; the twilight breeze on the shore; the ocean currents which traverse the waters. It is, again, he who sustains the vital principles of the air we breathe, the circulation of life in the organic kingdoms, in a word, the regular stability of the world. Lastly, it is to him we owe our intellectual life and the collective life of entire humanity, the perpetual food of our industry; and more than this, the activity of the brain which allows us to clothe our thoughts with a form, and mutually transmit them in the brilliant intercourse of intelligence.'

What imagination is powerful enough to comprehend the extent of the Sun's action on all the bodies subjected to its influences? A million and a half times larger than the Earth and seven hundred times larger than all the planets together, he represents the whole planetary system; and this system, which is a mere nothing compared with the stars, he draws through the deserts of space; and these worlds follow him at his will like dark passengers carried away by a splendid vessel on an endless sea. He makes them revolve round him, that they themselves may imbibe in their course the support of their existence, he governs them with his royal power and regulates their formidable movements. Addressing him, the poet may say without flattery :—

'Ta présence est le jour, la nuit est ton absence ;
La nature sans toi, c'est l'univers sans Dieu !'*

From these striking manifestations of his power, let us now descend to his hidden actions. Let us see his light and heat act on the organism of the planets which regard him with love and take long draughts of his fertile rays, on the electricity of minerals and on the diurnal variations of the magnetic needle, on the formation of clouds and the coloration of meteors ; let us see them, these occult influences of light and heat, descending through the pure air even to our very souls so eminently accessible to exterior impressions, and communicating to them joy or sadness ; and perhaps we shall begin to form an idea of what a ray of sunlight is, in the infinitely small of terrestrial nature as in the infinitely great of sidereal phenomena.

'Ce coin de soleil condense
L'infini de volupté.
O charmante providence !
Quelle douce confidence
D'amour, de paix, de beauté !

'Dans un moment de tendresse,
Seigneur, on dirait qu'on sent
Ta main douce, qui caresse
Ce vert gazon qui redresse
Son poil souple et frémissant.'

LAMARTINE.

But what is the nature of this powerful body whose action is so universal—what fire burns in this vast censer—what are the elements which constitute this splendid globe? Does it contain in itself the conditions of an infinite duration, or is the Earth rather destined one day to see this lamp of life extinguished and revolving henceforth in the darkness of an eternal winter? These questions belong to a lawful curiosity, and we wish that a satisfactory answer could be made to them. When we wish to appreciate the nature and greatness of a high person, we do not generally seek to prove his defects, to study the blemishes in his character; this would be a singular way of judging his value; and even were this so we owe it to human imperfection, from which the greatest of us are not free. But if referred to a being whose distinctive character lay precisely in being not only of a magnificent purity, but also the source of all light and purity, people would not seek for spots to understand him. Indeed, the learned were very astonished 260 years ago, when King Sun, the god of day, was accused by the telescope of being constantly covered with spots, and would it not be still more astonished if it discovered that these spots were precisely the only means that the Sun gives us to penetrate his nature? They almost believed on this occasion, that pride is in the inverse ratio of worth. The official *savants* of that time, the theologians and disciples of the school of Aristotle, were not willing to believe anything. The provincial father of the order of the Jesuits at Ingolstadt, replied to Scheiner, one of the first after Galileo who had seen the Sun and its spots through a glass, that Aristotle had proved that, in general, all stars were incorruptible, and that the Sun in particular was the purest light possible, consequently that the pretended spots of the Sun were in the glasses of his telescopes or in his eyes. When Galileo made the same observation, the Peripatetics exerted themselves to prove to him, books in hand, that the purity of the Sun was invincible, and that he had seen badly. And, indeed, who would have suspected such a thing? Spots on the Sun! This must be an error, and an evident delusion. In times of grave events, the Sun's disc lost, it is true, its light, as at the death of Julius Cæsar:—

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* Chènedollé

> 'Ille etiam extincto miseratus Cæsare Romam,
> Quum caput obscura nitidum ferrugine texit,
> Impiaque æternam timuerunt sæcula noctem.'—*Georg.* i. 466.

It was Virgil himself who related the fact, and the author of the *Metamorphoses* confirms it in a touching testimony:—

> 'Darkness, we see, emerges into light,
> And shining suns descend to sable night;
> E'en heaven itself receives another dye,
> When wearied animals in slumber lie
> Of midnight ease: another, when the grey
> Of morn preludes the splendour of the day.
> The disk of Phœbus, when he climbs on high,
> Appears at first but as a bloodshot eye;
> And when his chariot downward drives to bed,
> His ball is with the same suffusion red.'

But these were exceptions, and it would have been great rashness to conclude that the orb of day was subject to corruption. However, the Sun has spots, and the most curious fact is that these spots have enabled us to know its nature and physical constitution, whilst without them we should not have been able to acquire the slightest notion of the disposition of this great body. Recent ideas, based on the chemical analysis of its light, have not yet sufficiently advanced to contradict this assertion.*

Let us see then in what the spots of the Sun consist.

Generally, this is the aspect which they present to us in the field of the telescope. (See fig. 25.) Two very distant portions are noticed. At the centre a well-defined black region. Around it a region not so black or greyish compared with the surface of the Sun which surrounds it. The central part has received the name of umbra; sometimes at the centre of this part is noticed a more intense dark spot, which is called 'the nucleus.' The exterior region of the spot has received the name of 'penumbra.' When it is stated that the centre of the spot is black, this expression must be understood as relative to the general surface of the Sun; for this centre, however dark it may appear by contrast, has been found of a light equal to two thousand times that of the full Moon.

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* This reads strange in 1870!—Tr.

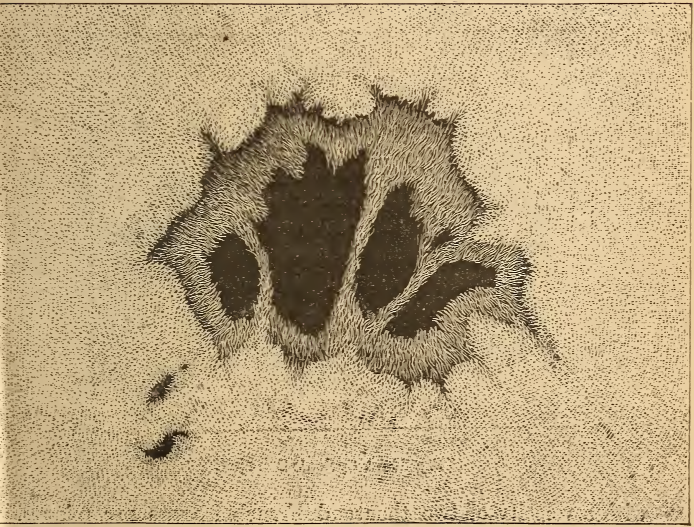

Fig. 25. A Sun-spot.

We may be led to the belief that these spots, generally invisible to the naked eye, are insignificant movements carried on on the Sun's surface, and of small extent. It is not so. They are daily and very important phenomena. Some of them have been known to measure 80,000 miles, that is to say, they are ten times larger than the Earth. Our globe falling into most of them would be lost as in a well. Besides being of this size, they are also the seat of various actions and prodigious phenomena. They are not formed suddenly as a whole, but increase to the limit they attain, and afterwards diminish. Some only last a few weeks, others months. Now the movements with which they are animated, either for their increase or diminution, or in their internal action, are sometimes of unheard-of rapidity. Lately, astronomers have followed a dazzling meteor passing through a group of spots with a velocity of two thousand French leagues per minute. In other parts, they have watched circular whirlwinds, dragging into their commotion large spots like the Earth, and swallowing them up in abysses with fearful velocity. Sometimes are seen the crests of stormy waves extending over parts of the penumbra, and rising on the white surface of the Sun as a still whiter and brighter substance, doubtless projected in their ebullition by interior forces. There have, besides, been seen immense bridges of fiery substances cast suddenly

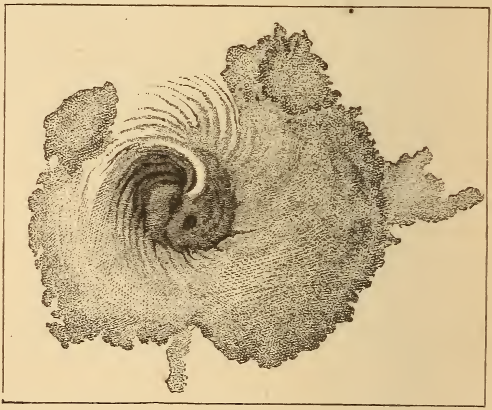

Fig. 26—A Cyclonic Sun-spot.

over a black spot, crossing it from one end to the other, like an arch of luminous striæ, which sometimes is dissipated, and falls down into the abysses of lower whirlpools. This body, which each day pours out over our heads such a pure and calm light, is the seat of powerful actions, and prodigious movements, of which our tempests, hurricanes, and waterspouts, give us but a slight idea; for these gigantic disturbances are not performed, as here, in an atmosphere of a few leagues thickness and over a few leagues area, but in proportions as vast as its atmosphere, which rises thousands of leagues above its surface,* and as its volume which exceeds 1,450,000 times that of our globe. One of the first results of the observation of solar spots was to discover that the Sun turns on its axis in about twenty-five of our days.

Indeed, if we watch for several consecutive days any of the spots visible on the solar surface, or a group of spots, or even the whole Sun, we shall not be long in remarking that the spots are all animated with the same movement from one edge to the other of the solar disk. If, for instance, we begin to follow a spot from its appearance at the eastern edge, we observe that it advances slowly towards the middle of the body, which it reaches about seven days after its appearance; then it passes it, and continues its course towards the west; and seven days after it reaches the edge and disappears.

After a period of fourteen days, employed in travelling over the opposite hemisphere, it reappears at the same place, and follows the path previously pointed out. These observations evidently show that the Sun turns on an axis. This rotation of the Sun shows its spots in the following manner:

If the period of the reappearance of the spots is from twenty-seven to twenty-eight days, this does not refute the number of twenty-five days before mentioned. The difference proceeds from the Earth not remaining immovable in space, but turning round the Sun. In order that we might observe directly the duration of rotation, it would be evidently necessary, as a first condition, that we should remain at the same place; for otherwise, if we turn round the body in the direction of its movement, we should still see the spots after the moment when they are invisible at the point where we were at first; and if we go in the contrary direction, we shall cease to see them before they cease to be visible at the same point. Now, in its translatory movement round the Sun, the Earth advancing in the direction of its rotation, sees the spots two days and a half after they have disappeared at the point where the Earth was at the commencement of the observation.

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* The recent spectrum observations tend to disprove this.—Tr.

This rotatory movement takes place from west to east, like that of the Earth and all planets of the system. Thus, by telescopic examination, this body declared fixed and incorruptible in antiquity, is stripped of its two distinctive qualities. The diurnal rotation of the Sun is twenty-five times longer than that of the Earth; but it differs essentially in its immediate consequences, because it does not produce on the surface the alternate day and night, which we derive from this movement. It cannot, then, be stated that this is the length of the solar day, for it is not the sign of a succession of light and darkness: the Sun's day does not go out, and the twilight of evening does not pale it. This world lives in a permanent light.

It neither knows our seasons nor years, and the elements of our calendar cannot be applied to its astronomical *rôle.* It seems that the rapid succession of things which constitute our time, and the changing series of phenomena which we experience, do not fall to his lot; continuance and endless duration are his appanage; and he is freed from counting for his individual personal life these successive ages which measure life and overwhelm it with their number. The great variety of nature separates it from the rank of the planetary world; and it would be a profound subject of astonishment to an inhabitant of the Earth if he were to visit a country so essentially distinct from ours, and to be able to establish a comparison between this strange world and his own.

## III.

## THE SUN—(CONTINUED.)

> ‘Quand le Soleil entra dans sa route infinie,
> A son premier regard, de ce monde imparfait
> Sortit le peu de bien que le ciel avait fait.’
>
> A. DE MUSSET.

WHATEVER may have been the preconceived idea by which opinions were regulated in favour of this beautiful Sun, this radiant body, so venerated that the idea of accusing it of spots was a blasphemy, it is nevertheless from observation and study of these spots that the knowledge we have of it has been acquired; so true is it that Science, superior to all prejudices, is the real ruler of the mind. The examination of these spots—their form, and the changing aspects which they reveal in consequence of the rotation of the Sun (Fig. 27), has served as a basis to a theory of its physical constitution which many astronomers have successively adopted and established, from Wilson and Herschel to Humboldt and Arago. According to this theory, the Sun is essentially composed of a nucleus and an atmosphere. The nucleus is dark, and the atmosphere is enveloped with a luminous stratum, to which has been given the name of ‘photosphere.’ The light and heat which it sends out to us does not come from the nucleus, but from this calorific and bright envelope. The spots are explained by supposing that they are openings formed in this outer envelope, either by gaseous eruptions issuing from volcanoes, or by powerful currents rising from the lower to the upper atmosphere, similar to vertical hurricanes, or by quite another cause dependent on the nature of the body. The penumbræ of the spots are formed on this theory by the lower atmosphere being endowed with the property of reflecting the light and heat of the photosphere and keeping it from the body of the Sun. The dark centre of the spots is nothing else but the body of the Sun itself, rendered visible by the aperture of the lower atmosphere corresponding to the opening of the photosphere. The spots are in this manner sufficiently explained, and also the different appearances observed on the solar surface, such as the pores with which it appears separated, faculæ or white spots, or ridges,—phenomena caused by chemical movements carried on in the atmosphere in which various gases are mixed in the most varied combinations.

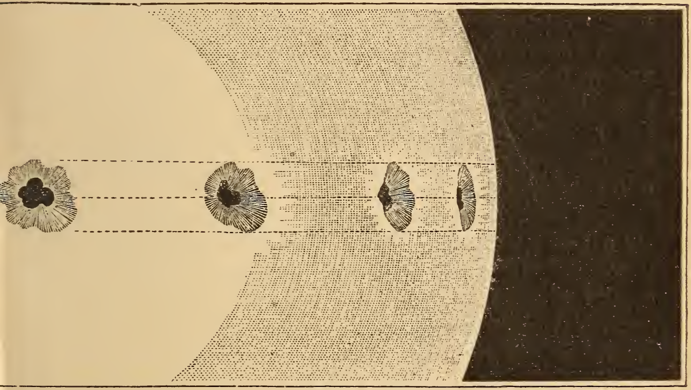

Fig. 27. The Sun's Rotation.

This theory has appeared much better established since the funnel-like aperture which forms the spots becomes still more perceptible by the perspective views afforded by the rotatory movement of the Sun. In virtue of this movement a round spot appears, and narrows in proportion as it travels further from the centre; and when the portion of the sphere where it is situated disappears, while it keeps its entire length, its width diminishes until it presents only the appearance of a line. Moreover, the portion of the penumbra, or, in other words, of the funnel which is on the side of the spectator, will diminish in width, and will disappear before the rest. Lastly, when a large spot arrives at the edge of the disc, if this spot is large enough, it ought to be seen slightly hollowing the part of the solar disk which it occupies. Now these appearances, regulated by perspective in the case of the spots being openings, are precisely those which are observed.

Astronomers are then generally of opinion that the solar nucleus is an opaque body, dark, like the Earth; that it is surrounded with a fluid atmosphere; and beyond this fluid lies a layer of substance endowed with the property of emitting light and heat; it is this outer stratum which is called the photosphere.

I say astronomers are generally of that opinion, for they are not all unanimous. A few years ago the physical sciences were enriched by a wonderful discovery, of which I shall speak further on, by which light may be analyzed—that is to say, the elements whence it comes may be known. Now, the English and Germans, to whom we owe this discovery, having examined the nature of the solar light, found that there were in the Sun's atmosphere iron, sodium, potassium, barium, &c., whilst there was no gold, silver, copper, or zinc. This would have been in opposition to the alchemists of past times, Nicolas Flamel in particular: the Sun was to them a golden body, *par excellence.* All these materials, proved to exist in the body by spectrum analysis, were also revealed as being in a state of incandescence. So much then for the experimenters and theorists of whom I speak—the orb of day returned to what it was to our fathers—a body of fire. Indeed, not only did they again state that the torch of day, far from being dark, is an incandescent globe: that the light we receive from it comes from its fiery nucleus, and not from its atmosphere; but they again sought to explain the spots on this new hypothesis, and they proposed to admit that these spots were simply clouds, combining with each other in the solar atmosphere under the influence of a partial fall of temperature, and becoming opaque enough to intercept the light of the incandescent globe almost entirely. Other *savants*, sharing the same ideas on the physical constitution of the Sun, threw out the idea that spots were not clouds, but partial solidifications of the surface—scoriæ, such as we see form on the surface of boiling metals treated in a crucible. They explained even how the umbra of the spots is the thickest central part of these partial solidifications, which intercepts the rays emitted by the solar body more effectually as it is more solid, and that the penumbra would correspond to the pellicle which, in every formation of this kind is observed on the surface of melting metals, to be produced invariably round the scoriæ. But although, having cleared science on some important points, and having rendered it good service, these researches are far from being ended, and founded on a solid theory; they have not yet upset the reigning theory before explained.*

The size of the Sun, 1,400,000 times larger than the Earth, exceeds the degree of our habitual measurements too much for us to hope to give a sufficient idea of it. In the matter of volumes, as in that of distances and times, the numbers too much surpass our ordinary conceptions to appeal to our minds, and every care that we take to represent them to ourselves remains almost sterile. Nevertheless, a comparison will be able to inspire at least a nearer idea of the size to which we refer. If we placed the terrestrial globe in the centre of the solar globe, like a kernel in the middle of a fruit, the distance of the Moon would be included in the interior of the solar body; the Moon itself would be absorbed in it, and beyond the Moon to the surface of the Sun, following the same radius, we should still have to traverse a distance of 160,000 miles. From the Earth to the Sun are reckoned 91 millions of miles. It is on account of this great distance that this immense body only appears to measure a foot in diameter; and this explains why the ancients, and Epicurus in particular, did not believe it larger than that measure. This distance equally explains why it does not appear to us larger then the Moon, which is only 240,000 miles away. From this it may reasonably be asked, how this distance from the Sun to the Earth could possibly be determined. The method is too complicated for me to explain it here in detail; but an idea may be given of it without exceeding the limits of this chapter.

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* A new light has recently been thrown on the question of the Sun's constitution by the spectroscopic examination of minute portions of its surface.—Tr.

Between the Sun and the Earth there are two planets, Mercury and Venus: the latter has rendered the greatest service in the study of the distance which separates us from the Sun. As its orbit (the circumference which it describes round the central body) is nearly on the same plane as the Earth's orbit, it happens from time to time that it passes between the Sun and ourselves, and appears like a black spot crossing the luminous disk. This passage takes place at the singular intervals of eight years, 113½ years—8 years, 113½ years+8 years. At these valuable periods, astronomers of all countries forget their nationality, and listening to each other like brothers, place themselves so as to observe the passage of Venus in different countries. Two observers situated in the stations most distant from each other, note the two points where the planet, seen from each of their stations, seems to be projected at the same moment on the solar disc. This measure gives them the angle formed by two lines starting from their stations, and crossing each other on Venus, and passing on to the Sun. It is the measure of this angle, made by observers placed on all parts of the globe, which gives what is named the parallax of the Sun.

At the last transit of Venus, a French astronomer, Le Gentil—his name should have preserved him from such disappointments on the part of Venus—was curiously requited for his love of science and his disinterestedness. Sent to India by the Académie des Sciences, he embarked with arms and baggage to observe the passage of the planet in 1761 at Pondicherry. His great activity and ardour could not conquer the chances of the sea voyage; he landed a few days after the phenomenon had taken place . . . . The obstacles irritated him and increased his courage. He took the heroic resolution of remaining for eight years in the midst of that unknown country, in order to compensate himself for his lost observation; he waited for the passage of 1769, and then took all desired arrangements to make a perfect observation. The year and the day at length arrived! The sky was pure, no obstacle hindered his long resolution from at last receiving its reward. But alas! exactly at the moment when the black spot was about to enter on the solar disk, a small cloud formed in the atmosphere and remained before the Sun until the moment when Venus left the disk, putting an end to the possibility of all observation. The astronomer again took the voyage to France with a stormy sea, which brought his days to a close. Le Gentil, of Galaisière, died in 1792, after having written an account of his travels.

From considerations based on the magnetic action of the Sun, we may be led to believe that its light is of the same nature as the electric light, only incomparably more powerful, seeing that the elements which we have at command are infinitely inferior to those commanded by nature. However bright our electric foci may be, however dazzling their light, the whiteness of which astonishes us when it is projected on the solar disc, the electric light has the appearance of a black spot.

The intensity of solar heat is not less difficult to conceive;

the most intense of our furnaces, which rise to the temperature of white heat, does not give us a faint idea of it.

However the following few comparisons will indicate its value. If we represent the Sun under the form of an enormous globe built up of a million four hundred thousand terrestrial globes, and covered entirely with a stratum of coal fourteen miles thick, the heat which it pours out annually in space is equal to that which would be furnished by this stratum of flaming coal. This solar heat would also be capable of melting in one second a column of ice which would measure 1590 square miles at its base, and 192,000 miles high.

Lastly, it is curious to inquire how much this gigantic body weighs. It is a good weight:—

2,154,106,580,000,000,000,000,000,000 tons!

If this globe were in the present day, as in that of Apollo, drawn by four horses, it would be necessary that the coursers had exceptional strength, especially to be able to go round the globe in twenty-four hours. Now, following the Sun's weight, that of our Earth, expressed like the preceding in tons is 6,069,000,000,000,000,000,000.

When astronomers place the Sun in one of the pans of the immense scales with which they determine the weight of the stars, it is necessary for them to put in the other one, 350,000 terrestrial globes to restore equilibrium.

We need not fear that this gigantic body will one day be extinguished, leaving the Earth in icy darkness. It possesses in its colossal reservoir a sufficient number of degrees of heat for us to have before us millions of centuries, during which it would be impossible for us, even if this heat should decrease, to perceive it.*

Yes, the resplendent star of day remains to us the most beautiful and the best of stars. We have observed its size and its power: no power is capable of rivalling it, science has not lessened its venerated image in our mind, and, as in our preceding studies, reality here is superior to fiction. Our homage remains, better understood and justified than ever.

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* Sir William Thomson has denied this.—Tr.

We can still say with Byron :—

'Glorious orb ! the idol
Of early nature, and the vigorous race
Of undiseased mankind, the giants' sons
Of the embrace of angels with a sex
More beautiful than they which did draw down
The erring spirits who can ne'er return.—
Most glorious orb ! that wert a worship ere
The mystery of thy making was reveal'd !
Thou earliest minister of the Almighty,
Which gladden'd, on their mountain-tops, the hearts
Of the Chaldean shepherds, till they pour'd
Themselves in orisons ! Thou material God !
And representative of the Unknown —
Who chose thee for His shadow ! Thou chief star !
Centre of many stars ! which mak'st our earth
Endurable, and temperest the hues
And hearts of all who walk within thy rays !
Sire of the seasons ! Monarch of the climes,
And those who dwell in them ! for near or far,
Our inborn spirits have a tint of thee,
Even as our outward aspects : thou dost rise,
And shine, and set in glory.'*

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* Lord Byron's *Manfred.*

## IV.

## MERCURY.

> ‘How dear to me the hour when daylight dies;
> And sunbeams melt along the silent sea,
> For then sweet dreams of other days arise,
> And memory breathes her vesper sigh to thee.’
> MOORE’S *Melodies.*

ABOVE the Sun, in the west, when that radiant body sets, or again before its rising in the east, is seen sometimes a small white star, slightly tinged with red. The Greeks called it Apollo, god of day, and Mercury, the god of thieves, who take advantage of night to commit their misdeeds; for they saw in it two different planets, one a morning and the other an evening one, as they did also for a long time in the case of Venus, the Egyptians and Indians doing the same. The first gave it the names of Set and Horus; the second those of Boudda and Rauhineya; names which bring to mind, like the preceding, the divinities of day and night. The Latins who, however, employed themselves very little with astronomy, in this respect remained in doubt. It has been only in later times that the identity of these two stars which, like Castor and Pollux, to which they are assimilated, never appear together, has been proved; its evening name, Mercury, was the one retained.

> ‘Dans l’océan de flammes incessamment plongé,
> Roulant sa masse obscure en un orbe allongé,
> Divers dans ses aspects Mercure solitaire
> Erra longtemps peut-être inconnu de la Terre,

> Cependant quand, le soir, le soleil moins ardent
> Laissait le crépuscule éclairer l'occident,
> Au bord de l'horizon une faible lumière
> Semblait suivre du dieu l'éclatante carrière.'
>
> DARU.

Being the first planet of the system, Mercury always remains absorbed in the royal radiation of the prince of day; also, like a courtier, it is deprived of its individuality and blended in the personality of the ruling star. It gains nothing and loses much, seeing that it had not the honour of being known to the founders of astronomy. Copernicus despaired of ever seeing it: 'I fear,' said this great man, 'that I shall descend to the tomb without having seen the planet.' And, indeed, he who had transformed the system of the world, and taken in hand each of the planets to place them round the Sun, died without having seen the first amongst them. Galileo was able to observe it, thanks to the glasses which he had invented, but it could not be said he understood it sufficiently, as it was impossible for him ever to distinguish its phases. The adversaries of the new system opposed the first astronomers, Copernicus, Galileo, and Kepler, on account of the absence of phases in the planets Mercury and Venus. 'For,' said they, 'if these planets revolved round the Sun, they would change their aspect to our eyes, as the Moon does, according as we see in front, in profile, or in rear, the illumined part, the side in fact which they turn towards the sun.'

Copernicus and his colleagues replied, 'We do not distinguish any phases, it is true; but if it only requires them in order that you should adopt our system, God will cause that there may be some.' Indeed there were some, and here (Fig. 28) are those of Mercury. By the observation of the irregularities visible in the interior of the crescent or quarter, it has been observed that Mercury is rugged with high mountains, higher than those of the Earth, although Mercury is a much smaller globe than ours. The existence of a denser and higher atmosphere than ours has been suspected. In the middle of the last century, one of the numerous romancers who feigned voyages to the planets, pretended to know that the mountains of Mercury were all crowned with beautiful gardens, in which grew naturally not only the most succulent fruits which served as food to the Mercurians, but also the greatest variety of dishes. It would appear that in this happy world, it is not necessary to prepare, as with us, things for food; fowls, hams, beefsteaks, cutlets, entremets, small side-dishes, &c., were raised there in the same manner as the apples on our apple-trees, and when a repast was wished for, it was sufficient to spread the cloth; then arrived bird-waiters for your orders, who knowingly flew away, and in the twinkling of an eye, from the mountains, where the desired dishes were to be found, brought you them with the greatest haste. It is better, perhaps, to believe that the vegetables of Mercury possess these precious gifts, and that its birds are of such delightful intelligence, than to think with Fontenelle, that the inhabitants of Mercury are all mad, and that

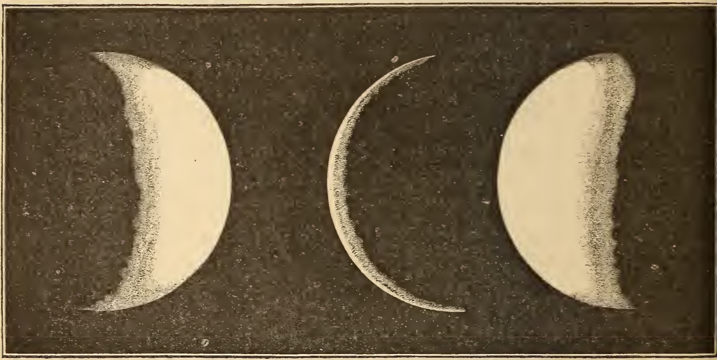

Fig. 28. Phases of Mercury.

their brains are burned with the violent heat which the Sun pours upon their heads. But until an authentic voyager has made us sufficiently acquainted on this head, we will confine ourselves to the astronomical elements of the planet. It revolves at a distance of 35 millions of miles from the Sun; its diameter is 2960 miles; its day is 24 hours, 3 minutes, 28 seconds long; its year, 87 days, 23 hours, 14 minutes; and its seasons, 22 days only; its mass, compared to that of the Earth, is only $\frac{17}{100}$; its density is three times more than ours, and bodies which fall on its surface travel 7.45 feet during the first second of fall; and, lastly, it receives six times and a half more light and heat than the Earth does. Its orbit is very excentric.

Excentric means that in its movement of revolution round the Sun it does not always remain at the same distance from it; that it describes an ellipse rather than a circle. As a result, at certain epochs of its year it receives twice as much heat as at the opposite epochs. It will be seen that the word excentric is not badly chosen, as it represents a want of regularity in the circular movement of the planet. While we are speaking of this singularity, let us also add that of all bodies Comets are the most excentric. At certain times they approach so near the Sun that it is thought that they will be melted in his flames; in the opposite part of their path, on the contrary, they go to such distances that they are lost to sight, and wander in the darkness and cold of solitary space.

## V.

## VENUS.

> 'Thou little sparkling star of even,
> Thou gem upon an azure heaven !
> How swiftly will I soar to thee
> When this imprisoned soul is free !'

The young poetess who sang this charming song, Maria Lucrezia Davidson, escaped from her earthly prison towards her well-beloved Star when she had scarcely seen her seventeenth spring blossom forth. Like the white morning and evening Star, she faded away at the first period of life, and only knew her dawn. Perhaps now even she resides in this isle of light, and contemplates thence the earthly abode which she not long ago inhabited ; perhaps she hears the prayers of those who, as she did formerly, allow their hopes to mount sometimes to the regions of the heavens.

Some ill-disposed minds have asserted that although Venus is beautiful afar, it is frightful on a nearer view. I fancy I see my young and amiable readers ; and I am sure that not one amongst them is of this opinion.

Indeed, all the magnificence of light and day which we enjoy on the Earth Venus possesses in a higher degree. Like our globe, it is surrounded by a transparent atmosphere, in the midst of which are combined thousands and thousands of shades of light. Clouds rise from the stormy ocean, and transport into the sky, snowy, silvery, golden and purple tints. At morning and evening, when the dazzling orb of day, twice as large as it appears from the Earth, lifts its enormous disk at the east, or inclines towards the west, the twilight unfolds its splendours and charms. From here we can be spectators of this distant spectacle ; for we distinctly see the daybreak and the close of day in the plains of Venus. Day and night are of nearly the same duration as on the Earth; the diurnal period of rotation of the planet is twenty-three hours, twenty-one minutes, seven seconds; it is consequently thirty-five minutes less than ours. But between winter and summer there is a still greater difference than with us between the intervals which elapse from the rising to the setting of the Sun and that which separates its setting from its rising; for this globe is more inclined to the plane of its orbit than ours. It is this inclination which constitutes on this planet as on the Earth, the variation of seasons, their duration and intensity. Venus being still more inclined than the Earth to the plane in which it moves, its seasons are more characteristic than ours, and its climate much more marked. Between the cold of winter and heat of summer there is a much greater difference than here; it is almost as cold in winter and very much warmer in summer. From the equator to the poles there is also a more decided variation of climates than on the terrestrial sphere; our temperate zones are imperceptible on Venus, and do not exist even. The torrid and glacial zones constantly encroach on each other; and as the year only occupies two hundred and twenty-four days instead of three hundred and sixty-five, the rapidity of this succession adds to its intensity. The snows, also, have not time to accumulate at the poles as on the Earth, Mars, and Saturn; and the atmospheric variations cause a continual disturbance on the surface of the planet. Its mountains are much higher than ours. They have been measured at the period when Venus presents itself to us as a crescent. The inequalities which are noticed in the interior of the crescent are the highest points of the surface which still receive the Sun's rays after these have left the plain. The height can be concluded from the time that these light-points take to disappear. We have just spoken of Venus as a crescent. Like Mercury, this planet is situated between the Earth and the Sun; and the circle which it describes during its year is comprised in the circle which the Earth describes round the same body. Hence it follows that at certain epochs the planet Venus is exactly between us and the Sun; and then it presents its dark part to us, as its illuminated portion is naturally on the side of the Sun. At other times, when it is to the right or left of the Sun, it presents only a quarter. Lastly, when Venus is on the other side of the Sun, it presents its entire illuminated portion to us.

As Venus revolves in an orbit, there are periods when it is only about twenty millions of miles from us (when it is between us and the Sun), and contrary periods when it is 157 millions of miles distant from us. Its apparent dimensions then vary very perceptibly with its distance. Fig. 29 shows these variations.

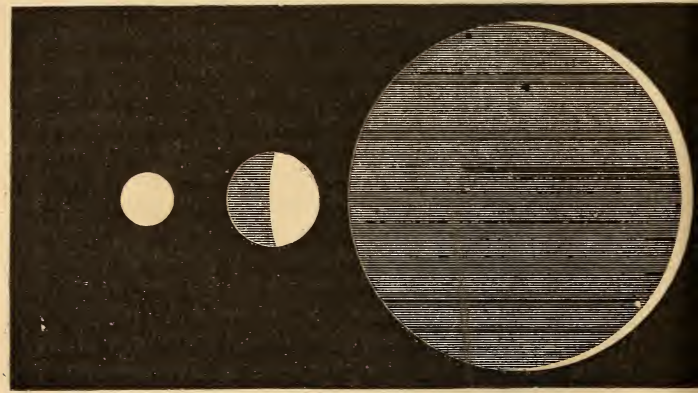

Fig. 29. Variations of the apparent disk of Venus.

The phases of Venus were seen for the first time by Galileo in the month of September, 1610, who beheld this spectacle with a joy impossible to describe, seeing that it eloquently testified in favour of the system of Copernicus, showing that like the Earth and Moon, the planets receive their light from the Sun. When I say that these phases were for the first time seen in the month of September, 1610, you must not conclude that they did not exist before that epoch, but you must understand, that before that year no one had turned the telescope to the planet, and that with the naked eye, these phases are imperceptible.

According to the custom of the period, the illustrious astronomer disguised his discovery under an anagram, to maintain the authenticity of this discovery in case of rivalry, and to give himself time to continue his observations and to perfect them. He finished a letter with this phrase : 'Hæc immatura a me jam frustra leguntur, d. y.' which means, 'These things unripened and as yet hidden to others, are at length read by me.'

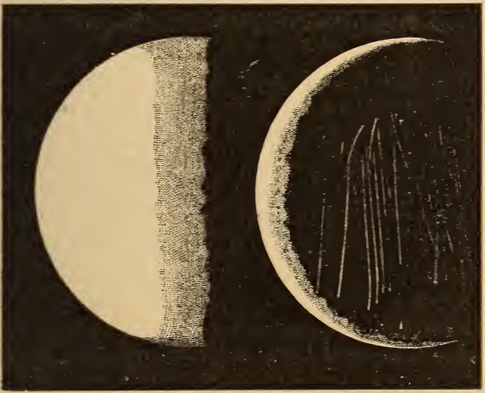

Fig. 30. Inequalities of the crescent of Venus.

Under this cryptogram, it would be difficult to discover the idea of the phases of Venus. Our fathers were very ingenious, and in the present time certain discoveries would not have been so greatly contested, if astronomers had sometimes used the same ruse. In this phrase there are thirty-four letters. By placing them in another order, we get these words, in which the whole discovery is elegantly inscribed: 'Cynthiæ figuras emulatur mater Amorum.' 'The mother of the Loves puts on the phases of the Moon.'

Galileo was very cunning. Two months later, Father Castelli asking if Venus had phases, he replied, 'My state of health is very bad, and I find it better to be in my bed than in the dew.' It was only two days before the end of the year that he announced the above discovery.

Has Venus a satellite? 'It would rather have two than one,' replied the friend of Cassini to the enemies of this astronomer. Many hold the firm belief of having seen it, but the question remains undecided. In the middle of the last century, it was so strongly believed in, that Frederick the Great, of Prussia, proposed to give it the name of his friend Alembert, from which the illustrious geometer excused himself in this little note: 'Your Majesty does me too much honour in wishing to baptize this new planet with my name. I am neither great enough to become the satellite of Venus in the heavens, nor well enough to be so on the Earth, and I know too well how small a place I occupy in this lower world to covet one in the sky.'

This globe presents the greatest resemblance to our own; and it has nearly the same astronomical elements, size, volume, weight, and density; only it is much nearer to the Sun than we are. From the commencement of ancient poetry, its position near the Sun, which causes it to appear at sunrise and sunset, attracted contemplative minds towards it, and Venus became the star of all those who love to dream in the evening, from the shepherd returning from the fields to bosom friends whose souls commune with each other during the night. In the middle ages, a worthy father took an ecstatic voyage in the heavens, and in Venus saw only young people of ravishing beauty, living in the midst of perfect happiness; in his sight, these were the guiding spirits of the planet Venus, for in olden times it was believed that a legion of angels or genii presided over the direction of each of the heavenly spheres. Later, the author of 'Paul and Virginia' gave the most wonderful description of Venus; it was a real terrestrial paradise. In our time, the poet of the 'Contemplations,' visiting the ancient isle of Cythera, which is now only a desert and bare rock, carries his mind back to the heavens, and there seeks the dwelling of Venus:

> 'Venus! que parles-tu de Vénus? elle est là.
> Lève les yeux. Le jour où Dieu la dévoila
> Pour la première fois dans l'aube universelle,
> Elle ne brillait pas plus qu'elle n'étincelle.
> Si tu veux voir l'étoile, homme, lève les yeux.
> L'île des mers s'éteint, mais non l'île des cieux;
> Les astres sont vivants et ne sont pas des choses
> Qui s'effeuillent, un soir d'été, comme les roses.
> La terre à Cérigo, mais le ciel à Vénus.'

May the golden rays of this beautiful star still shine long on our evenings, opening to our minds a series of reveries which for the time transports us to the celestial world. May it still announce the starry *cortège* of still nights, and may it be the forerunner of peaceful and silent hours, which rock the soul in dreams of the past.

> 'Etoile qui descends sur la verte colline,
> Triste larme d'argent du manteau de la nuit,
> Toi que regarde au loin le pâtre qui chemine,
> Tandis que pas à pas son long troupeau le suit.
> Etoile! où t'en vas-tu dans cette nuit immense?
> Cherches-tu sur la rive un lit dans les roseaux?
> Où t'en vas-tu si belle, à l'heure du silence,
> Tomber comme une perle au sein profond des eaux?
> Ah! si tu dois mourir, bel astre, et si ta tête
> Va dans la vaste mer plonger ses blonds cheveux,
> Avant de nous quitter, un seul instant arrête,
> Etoile de l'amour, ne descends pas des cieux!'
>
> A. DE MUSSET.

# VI.

## MARS.

'Je reconnais ses traits, c'est le farouche Mars !
Sa pâleur que nuance une rougeur obscure
Sans peine à tous les yeux distingue sa figure :
Empreinte sur son front, cette sombre couleur
Du dieu dont les guerriers admirent la valeur
Nous peint la cruauté, la fureur homicide,
Et du sang des humains sa soif toujours avide.
Rien ne peut adoucir sa barbare fierté.
Des mortels et des dieux son glaive détesté
Souille toujours de sang sa funeste victoire.

. . . . . . . . .

A son cruel aspect, la paix, la douce paix,
S'éloigne, et des mortels retire ses bienfaits.
De nos champs ravagés on voit fuir l'abondance.'

RICARD.

As you see, poor Mars has not been spared. All the maledictions of mortals have fallen on Saturn and Mars. Beginning with war, that scourge of humanity of which it will have great trouble to rid itself, all public misfortunes caused by power have been attributed to Mars, who if it knew what the Earth thought of it, ought to regard us with an evil eye. It is, nevertheless, innocent of all these calumnies, and we ought not to speak ill of it, presenting, as it does, most resemblance to ourselves. Indeed the world of Mars resembles the Earth so much, that if we happened one day to be travelling there and lost our way, it would be almost impossible to recognise which of the two were our planet. Without the Moon, which would charitably remove our uncertainty, we should run a great risk of arriving amongst the inhabitants of Mars, expecting to descend into Europe or some other terrestrial quarter. Indeed, the planet Mars in our telescopes presents the same aspect as the Earth must do to the inhabitants of Venus; a circular disk, rather flattened, turning on itself in about twenty-four hours, furrowed from time to time by fleeting clouds, diversified with here dark and there light plains; revolving obliquely on an axis enveloped with an atmosphere and with snow-covered poles. On this planet the seasons are nearly of the same intensity as our own, but their duration is twice as long; for Mars only accomplishes its annual revolution round the Sun in 1 year, 321 days, and 22 hours, or 1 year, 10 months, and 21 days. The masses of ice we see at its poles partly melt in the spring of each hemisphere, and again form in the autumn, as occurs on our globe; and as the seasons are complementary on both hemispheres, the southern pole diminishes while the northern pole increases, and alternately. From this melting of snows result the changes of temperature and the cloud-

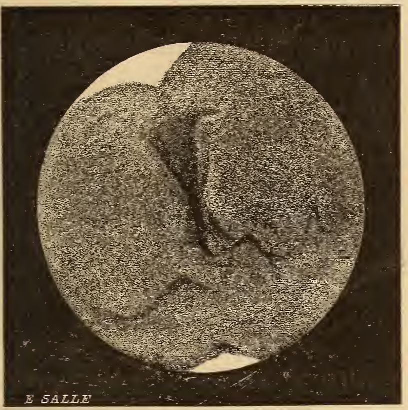

Fig. 31. Mars.

movements which are observed; one part of the water is evaporated into clouds, the other part swells the rivers and descends to the sea. Thus the fundamental characteristics of the terrestrial seasons are again found on the neighbouring planet.

We may, nevertheless, notice certain differences between the aspect of Mars and our own world. Whereas the Earth seen at a distance must appear tinted with green, on account of the colour of its atmosphere, its vegetation and waters, Mars is shaded with red, and it is this shade which gives it the reddish light with which it is seen to shine. Doubtless this characteristic colour is produced by the dominant colouring of its surface, either its soil is thus coloured like that of our deserts, or its seas, its vegetation, or the vapours rising into its atmosphere, are chiefly clothed with this shade. Nevertheless, the poles always preserve their brilliant light. An ancient philosopher, Anaxagoras, stated that snow was black: his paradox had been somewhat smoothed or cleared if the snows of Mars, each time that we were able to perceive them distinctly, had been red; but they are white also. 'The colour of the polar markings,' said Beer and Mädler, two astronomers whose lives have been devoted to the study of Mars and the Moon, 'is always of a bright and pure white, in no way similar to the colour of the other parts of the planet. In 1837, it once happened that Mars was, during the observations, completely darkened by a cloud, with the exception of the poles which stood out distinctly.'

Moreover, is the water of Mars the same as the water on the Earth? Father Kircher was asked if that of Venus would be good for baptizing? and it was not doubted. We ask ourselves whether there are the same chemical elements as there are here, and we doubt it. That the polar markings of Mars are masses of ice and snow, seems proved by observation, as the changes which they undergo annually are occasioned, as with us, by the apparent movement of the Sun.

This fact has been abundantly proved. When a snow zone is of large extent it is after the long winter of the pole to which it belongs; when the same spot is very small, it is after a summer which has melted and successively contracted it. But from this it must not be concluded that the term snow signifies anything but an appearance, and there is no plausible proof to be relied on that the substance that we know under the name of snow is actually seen there, that is to say, water (chemically, an equivalent of hydrogen and oxygen: $H_2O$) frozen into small needles. It is, on the other hand, possible that the constituent elements of the globe of Mars are very different from those with which the Earth is formed, and their chemical combinations having been from the beginning submitted to other influences than those which are at work on our globe, there may exist but a remote analogy between the nature of this world and our own, and not an identity of matter.

Removed from the Sun to a mean distance of 139 millions of miles, and encircling the Earth's orbit in that which it describes round the central body, there are certain periods when these two planets are very near together; that is, when they are both on the same side of their path with regard to the Sun. Sometimes they are not more than 48 millions of miles distant from each other. It is this which makes Mars, after the Moon, best known to us, so that Kepler was able to say: 'It is from the knowledge of Mars that astronomy will reach us, and it is from the study of this planet that the future progress of our science will advance.'

The conjunction of two planets is the point of their orbits where they are on the same side of the Sun, and are the nearest possible to each other; the term opposition is given to the opposite point of their paths, when they are on opposite sides of the Sun, except in the case of Mercury and Venus. In olden times these positions greatly exercised the sagacity of horoscope-seekers, and heaven knows how many destinies have received fancied predictions, according as the god of war was in conjunction in such and such sign of the zodiac. The conjunction in the Bull was not at all the same as that which happened in the Virgin; and when by chance it had the misfortune to occur in the Goat, the most learned were lost in conjectures on the bad fortune predicted to the new-born. The interior planets, Venus and Mercury, whose orbits are enclosed in that of the Earth, have no opposition, but they have two conjunctions; the superior, when the planet is beyond the Sun and in one right line; the inferior, when it is situated between the Sun and the Earth. The exterior planets, those which inclose the terrestrial orbit, and of which Mars is the first, have only the superior conjunction.

At about 80 millions of miles, beyond the planet Mars, between the orbit of this planet and that of Jupiter, we meet with the group of small planets, of which we have already spoken. These are very little worlds, if even they deserve this name, which have scarcely the extent of a province, or even a department. They gravitate in this zone in considerable numbers, for there may exist several thousands. Already 109 have been discovered: the first in 1801 and the last in 1870.

Perhaps they are *débris* of a larger world, shattered by some catastrophe; perhaps they have been formed in this region of space in the fragmentary state in which we now see them. This is not decided, seeing that science now, as in the time of Virgil, is not yet able to determine on the origin of things.

> 'Felix qui potuit rerum cognoscere causas.'

Putting aside the title of original greatness of these asteroids, and the fate which attends them, let us traverse their colony, and beyond it get near the most magnificent of the worlds of our system.

# VII.

## JUPITER.

'—She said,
" Oh ! that it were my doom to be
The spirit of yon beauteous star,
Dwelling up there in purity,
Alone, as all such bright things are ;—
My sole employ to pray and shine ;
To light my censer at the sun ! " '
MOORE's *Loves of the Angels.*

THE orb of Jupiter is more bulky than all the other planets of our system : it is only a thousand times smaller than the Sun, which makes it, if we remember the volume of that radiant body, from fourteen to fifteen hundred times larger than the terrestrial globe. Also, although it revolves in an orbit nearly 475 millions of miles distant from the Sun, and receives a much fainter light than that received by the Earth, its size is evidenced by the light with which it shines during our starry nights, equal and often superior to that with which Venus shines. Jupiter is therefore reckoned among the most beautiful objects of the heavens. As it is always in the zodiac, and when Venus is visible in the evening, it is always in the west, it is easily recognised. At whatever period of the year, therefore, you see a very bright star, either in the east, or high up among the zodiacal constellations, you may be certain that it is Jupiter.*

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* A great many persons are desirous of being able to observe the planets among the stars, and of knowing in what part of the sky they may be found each night of the year. It is to supply this want that in the author's *Etudes et Lectures sur l'Astronomie*, he has completely calculated and described the astronomical phenomena of each month, and sketched on a celestial map the future paths of the planets.

This planet is a charming one, so far at least as we are able to judge from afar and without going there. To begin with, a continual spring rejoices its surface. If it is ornamented with flowers, which we do not doubt, though we know not of what these flowers consist, they do not only survive 'the span of a morning' as our roses do, but live much longer. Scarcely have the oldest begun to dry up and fade but they are replaced by lovely buds, opening before the first have died away. Not only is the Jovian year equal to twelve of ours, but it is scarcely known when the yearly period begins or ends. No winters, no summers, always spring.

Then Jupiter, as I have stated, presents a surface 126 times more extensive than the terrestrial surface. I speak of surface, not volume. Now, a hundred and twenty-six Earths placed side by side, and on which the human race would be able to spread itself at will, would constitute a very fine country. We ought, then, not to doubt that such an empire has been formed to serve as an abode for a human family, venerable and worthy of our respect. We reason thus *apropos* of Jupiter, because we have had the necessary means to measure and appreciate it at its just value. But it is necessary to add something to complete the comparison between this world and our own.

Because we find, by observation of the Jovian planet, excellent reasons for believing that its inhabitants are very favoured, it does not follow that the aforesaid inhabitants make similar reflections on us. There is a very good reason why they do not occupy themselves with us,—they are probably not acquainted with our existence. And, indeed, if ever, at a future time, more or less distant, you should happen to inhabit Jupiter, you would have great trouble to discover your old country. To do so you would have to rise a little before the Sun (and mark there are only five hours from the setting to the rising of this body on Jupiter) and five or six minutes before the rising look to the east for a very small white star. With good eyes, you perhaps would perceive it.

In this case, you would know that our Earth exists. Again, you would make the same search six months later, at the west, a few moments after the setting of the Sun. Such is the condition of the inhabitants of Jupiter with regard to us. They can never see the Earth during the night, although it is precisely in the middle of clear nights that we are best able to observe this magnificent planet.

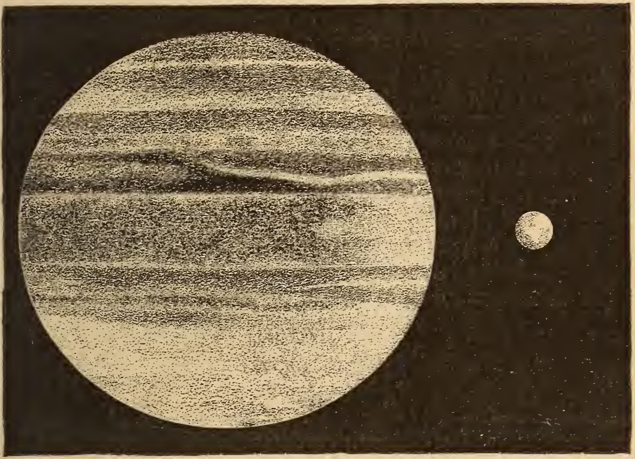

Fig. 32. Jupiter and the Earth.

No. Jupiter is an earth, a splendid earth compared to which ours is only a moon.

If we were allowed to observe Jupiter closely and to accustom ourselves to its nature, to live for some time in the midst of its train and to appreciate all its importance, we should think our globe very small after such a stay. We should be like the good villagers who came once in their life to see Paris, and who, if they had the misfortune to remain there only a month, could not even think of their village; it became eclipsed by the single remembrance of the splendour they had glanced at. This is precisely what our poet Beranger writes :—

‘Dans mon vol, sous mes pieds, qu’entends-je ?
C’est le triste son d’un pipeau,
Qui mène au gré d’un tout jeune ange
L’un des corps nains du grand troupeau,
Petit globe, objet de risée !
On dirait à le voir courir,
Du savon la bulle irisée
Qu’un souffle fait naître et périr.

‘Je demande à l’enfant céleste
Si c’est son jouet dans les cieux,
—Enorme géant, sois modeste,
Dit-il, regarde et juge mieux.
Je me penche alors sur la boule,
Prêt à la prendre dans ma main !
Dieu ! j’y voir s’agiter la foule
Que nous nommons le genre humain.

‘Ma confusion est profonde,
Et-ce donc là notre séjour ?
—Oui, dit l’ange, voilà ce monde
Dont peu d’entre vous font le tour.
Ton œil y distingue sans doute—
Ces monts qui sont géants pour vous,
Et votre Océan, cette goutte
Qui suffit à vous noyer tous.’

# VIII.

## SATURN.

> ‘Seul dans notre système,
> Il marche le front ceint d'un double diadème.
> Quels tableaux variés doivent offrir aux yeux
> Ces deux écharpes d'or flottantes dans les cieux !
> Oui, Saturne, à bon droit, en contemplant sa masse,
> Ce soleil qui pour lui n'est qu'un point dans l'espace
> Ses gardes, sa couronne et leurs orbes divers,
> Peut se croire le roi, centre de l'univers.’
>
> DARU.

If you happen one day to take a little journey to the planet Saturn, which is scarcely more than 900 millions of miles from us, you would feel on approaching it an unspeakable astonishment, to which certainly no sentiment of surprise felt on the Earth can be compared. Imagine an immense globe, not only of the size of the Earth, but as large as 734 Earths put together. It revolves on an axis with such rapidity, that in spite of its size it accomplishes its diurnal rotatory movement in about ten hours. Around it, at 20,000 miles distance, above its equator, an immense ring, flat and relatively very thin, surrounds it on all sides. This ring is followed by a second, and this one by a third. Now, this system of multiple rings is only a few miles thick, whilst its diameter is 166,000 miles. They do not remain immovable, but are carried along with a circular movement round the planet, this movement being of still greater rapidity than that of the planet itself. The domain of the Saturnine world is not confined to this. Beyond the ring, eight moons are seen revolving in the heavens around this strange system;

the nearest of these satellites is separated from the planet's centre by a distance of 120,000 miles; the most remote has an orbit of 2,293,000 miles from the centre of the planet. Saturn then governs a system which measures not less than four and a half millions of miles in diameter.

By the side of this world the Earth makes but a poor figure, and Micromegas was to be pardoned when on coming out of Saturn he mistook the Earth for a mole-hill. Its years are thirty times longer than ours; of its seasons each lasts seven years and four months; a change remarkably like that which distinguishes our own diversifies them; a regenerating spring succeeds the rigour of winter; summer and autumn pour forth their alternate fruits. But the phenomenon which draws most attention to this world is that gigantic ring which surrounds it. It was long before astronomers were able to give any account of this singular appendage in the planetary system.

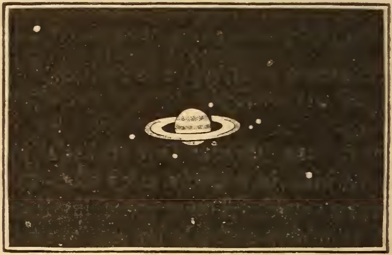

Fig. 33. Saturn and its Satellites.

Galileo, who first saw on each side of Saturn something bright of which he could not distinguish the form, was greatly astonished with such an aspect. He first announced it under an anagram, in which Kepler himself could not discover anything, and as he had done with Venus, disguising his discovery he gave himself time to bring it to perfection. He called it three-bodied for want of better knowledge. 'When I observe Saturn,' he wrote later to the Ambassador of the Grand Duke of Tuscany, 'the central star appears the largest; two others, situated, one to the east, the other to the west, and on a line which does not coincide with the ecliptic, seem to touch it. They are like two servants who enable old Saturn to continue his road, and they remain always at his side. With a glass of small power, the star appears lengthened and of an olive form.'

The laborious astronomer sought in vain; he was not favoured in his researches as in the preceding ones. At the period when the edges of Saturn's rings are presented to us, they disappear on account of their thinness. Galileo, finding on a certain night the absolute impossibility of distinguishing anything on either side of the planet, where, a few weeks before, he still observed the two luminous objects, was completely in despair; he came to the belief that his glasses had misled him. Being entirely discouraged, he no longer observed Saturn, and died without knowing that the ring existed. In the same way later, Hevelius declared he was puzzled, and it was not until 1659 that Huygens, the real author of the discovery of the ring, made the first satisfactory observation and explained its structure. With the contemporaries of Galileo, Saturn was considered to be a bowl with handles; or a cardinal's hat. In the middle of the eighteenth century, Maupertuis conjectured that the ring was only a comet's tail, wound like a turban round the Saturnian globe. Towards the end of the same century, Du Séjour wrote his 'Essai sur les phénomènes relatifs aux disparitions périodiques de l'anneau de Saturne,' in which he found, theoretically, the time of rotation of the ring: he presented his work to Voltaire with the following graceful dedication:—

'Monsieur, accept, I pray you, the history of a respectable old man, with whom they will busy themselves on the Earth, whilst to know him will be an honour among men; his forehead is wreathed with an immortal crown; he shines on us, and presents one of the most singular phenomena of nature. This aged person is Saturn. I hasten to name him lest he have another given him, which your modesty would prevent you from recognising. May this analogy gain for my work a favourable reception from you!'

Without the last remark, Voltaire himself, and sooner than any one else, might have thought that Saturn had very little to do with the dedication. At this time, Saturn's system included, besides its rings, five satellites revolving round it. Since that time three others have been added, and the cortége is composed of eight members. The following table shows the order of their distances from the planet, their names, the order of their discovery, the discoverers, and date of the discoveries:—

| | | | |
|---|---|---|---|
| 1. | Mimas | Herschel | 1789 |
| 2. | Enceladus | Herschel | 1789 |
| 3. | Thetis | Cassini | 1684 |
| 4. | Dione | Cassini | 1684 |
| 5. | Rhea | Cassini | 1672 |
| 6. | Titan | Huygens | 1655 |
| 7. | Hyperion | Bond and Lassell | 1848 |
| 8. | Japhet | Cassini | 1671 |

Saturn has not been favoured by ancient poets, who did not guess at its grandeur and richness. Situated at the extreme limit of the planetary system, and marking the frontier until the period of the discovery of Uranus, he was considered as the coldest and slowest of all bodies. It was the god of Time, dethroned and banished in a sort of exile. Misfortune to those who were born under its influence! If, at the moment of birth, it was in the zodiacal sign of the month, the newly-born had nothing more to ask than to go again into nothingness. For a thousand years, a considerable number of serious men had full and entire faith in horoscopy, themselves deceived through ignorance and often

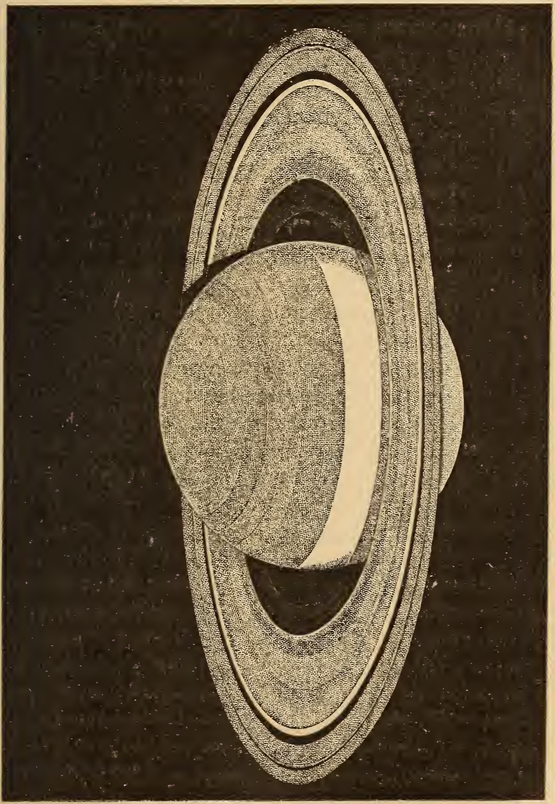

Fig. 34. Saturn.

in sincerity. These ideas, happily having given way before the light of science, are too curious for me not to give a slight specimen. Hear, for example, an astrologer, who wrote, in 1574, the following absurdities :*—

'Saturn is in the seventh heaven. He makes rustics; signifies peasants, labourers, and mercenaries; makes thin, solitary, and dreamy people, who, when walking, keep their eyes to the ground; it also signifies stooping, old people, Jews and beggars, mechanics and people of low condition, and causes death, ice, and epidemics; in short, it has no light except that which others impart to it.' So much for the conditions; but this is as nothing to the influence of this unfortunate on diseases.

'Saturn,' says La Martinière, 'is a dull, dry, nocturnal, and malevolent planet, to whom are attributed long, quartan, or daily fevers, indispositions of the tongue, arms, and bladder, general paralysis, gouts, abscesses, obstructions of the heart and spleen, the black jaundice, polypus, diseases of the intestines—such as windy colics, piles, hemorrhoids, hernia, corns on the feet, spitting of blood, canine appetite, difficulty of breathing, stones in the loins and bladder, epilepsy, cachexy, dropsy, melancholy, leprosy, and other diseases proceeding from foul and putrifying humours . . . .' (all cannot be quoted). Those who are born in its season are melancholy and phlegmatic.' Saturn has no idea of having caused such misfortunes to the inhabitants of the earth. Let us hope, for our reputation there, that astrologers in Saturn will not have used reprisals; for then, of what sorcery will they not accuse us? But we have good reason for believing that we are not viewed ill by the Saturnians; for this reason (which, however, does not do us great honour), that from Saturn they do not see the Earth, as our globe is too small, and is hidden by the Sun.

According to a still more singular author, the devil may be made to appear to us, by invoking him, on the Sabbath-day, Saturday, consecrated to Saturn, by a cabalistic formula, extremely long and difficult to pronounce, and by presenting to Saturn a perfume composed as follows ;—' Mix the seed of poppy and henbane, mandrake root, powdered loadstone, and good myrrh: reduce these drugs to fine powder, and mix them with some blood of bats and brain of black cats,' &c. I will not give the whole, lest you might try the recipe.

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* La Taille de Bouderoy, *Géomancie abrégée.*

Each planet influenced the destinies of men, according to the date of their birth. Thus in the first sign of the zodiac, 'Jupiter made bishops, prelates, nobles, powerful people, judges, philosophers, wise men, merchants, and bankers. Mars signified warriors, firebrands, murderers, doctors, barbers, butchers, goldsmiths, cooks, bakers, and all trades having to do with fire. Venus produces queens and beautiful women, apothecaries (how well that follows!), tailors, workers in jewels and ornaments, cloth-merchants, gamesters, those who frequent public-houses, those who play with thimbles, libertines, and brigands. Mercury produces clerks, philosophers, astrologers, geometers, arithmeticians, Latin authors, painters, ingenious and cunning workmen, both men and women, and their arts.'

Mars may be compared to Saturn for the bad reputation given to it by astrologers. The following sentence will suffice to show this: 'People over whom Mars presides are rough, rude, and invincible, and can be prevailed upon by no reason; they are obstinate, quarrelsome, rash, daring, violent, and accustomed to be deceived by report; gluttons, digesting various meats; strong, robust, imperious; with bloodshot eyes, red hair, not possessing affection towards their friends, but exercising the arts of fire and sword; in short, Mars generally produces furious, quarrelsome, dissolute, self-conceited and choleric men.'

As to Venus, no star has had such a favourable influence. It is useless to state in what its action chiefly consisted; but it appeared that those over whom it presided were most happy mortals. These odd and erroneous ideas on a pretended influence of the planets, and all those which constituted the vast astrological domain, arose from man's superstition, which is always attracted towards the wonderful, and his pride, which represented the universe as formed expressly for him. As long as the old system of the world, founded on appearances, reigned, man was a prey to this morbid error. The torch of true science—of science founded on discussed observations and calculation, was alone capable of bringing light into the midst of this darkness, and dissipating it in proportion as man shall rise more in true knowledge. It will be a more glorious title of honour for the centuries which are to come, to have delivered the human mind from these illusions, and for ever to have triumphed over them. Often, in those times when man's life was so easily sacrificed, astrologers, alchymists, and sorcerers were burned alive, hung, broken on the wheel, beheaded, quartered, or executed by long tortures, for having predicted badly. I could point out hundreds of sorcerers burned for pretended witchcraft, or for profanations which arose rather from their credulity than their wickedness; astrologers hung or drowned according to the good pleasure of princes; seekers of the philosopher's stone executed for having made a compact with the devil, but this is not the place; and in speaking of astrology in this chapter on Saturn, I have only wished to profit by the circumstance to show once again what benefits we owe to science, and to what depths man could again fall if ever the torch of science were extinguished. Saturn's world deserves something better from our hands. Not only do we deny the sinister influences of which he is the supposed author, but again we admire in him a magnificent abode of life, in the midst of which the forces of nature continue under aspects which are still unknown to us. Amid his splendid rings, and rich system of eight moons, he reigns peacefully in the heavens; and we love to contemplate his venerable figure, in those distant regions, as the type of a creation already advanced in that era of perfection to which all beings aspire. This disquieting Saturn has not always been treated with more respect by the moderns than by the ancients; has it, in its turn, a bad star? Some people still regard it with an evil eye,—for instance, the author of the 'Contemplations,' made it the place of chastisement of wicked souls, whilst the happy ones passed from sphere to sphere:—

'Chacun ferait ce voyage des âmes
Pourvu qu'il ait souffert, pourvu qu'il ait pleuré.
Tous, hormis les méchants, dont les esprits infâmes
Sont comme un livre déchiré.

'Ceux-là, Saturne, un globe horrible et solitaire,
Les prendra pour un temps où Dieu voudra punir,
Châtiés à la fois par le ciel et la terre,
Par l'aspiration et par le souvenir!

'Saturne! sphère énorme! astre aux aspects funèbres!
Bagne du ciel, prison dont le soupirail luit!
Monde en proie à la brume, aux souffles, aux ténèbres,
Enfer fait d'hiver et de nuit!'

This would be hateful! Let us hope that there are in this picture reminiscences of the ancient ideas on Saturn, and that this globe is less frightful than it looks to the prejudiced. This strange world does not want for riches; and if we were able one day to visit it, doubtless we should find it much more beautiful than the Earth, and we should vow henceforth to reside in such a royal and majestic domain.

Saturn, in the eyes of the ancients, kept the frontier of the solar empire, of which the composing Seven would not see their number increased. Science, daring and independent, which despises opinions and prejudices, has without scruple passed this barrier, and discovered two new worlds, which extended the ramparts of the solar domain three times beyond their old position.

## IX.

## URANUS.

'Mais la philosophie, en sa veille assidue,
De la création explore l'étendue :
Œil sublime, elle prend son vol audacieux,
Du système elle atteint la borne qui s'efface . . .
Quel est au loin, là-bas, ce globe merveilleux,
Ce nouveau monde errant qui sillonne l'espace ?
C'est Uranus ; il suit son cours majestueux,
Réfléchit du soleil la lumière émanée
Et roule lentement sa languissante année.'

Hélèna-Maria Williams.

On the 13th of March, 1781, between ten and eleven in the evening, a quondam organist of Halifax, who had himself made the best telescope then in existence, observed the small stars of the constellation of the Twins, with a telescope of nine feet focal length, and a magnifying power of 227. During his observation he perceived that one of the stars presented an unusual diameter. Astonished and desiring to prove the fact, he took an eyepiece magnifying double, and found that the diameter of the star increased whilst that of the others remained the same. More and more surprised, he fetched his magnifying power of 932, being quadruple that of the first, and again observed it. The mysterious star was still larger. From that time, he no longer doubted ; this was a new body, not a star. He continued the following days, and noticed that it slowly moved among the others. It was then a comet. Herschel described it to the Royal Society in a paper entitled, 'Account of a Comet ;' and the scientific world of all countries registered this new cometary body, and set about observing it in order to determine its orbit.*

The name of the astronomer was then so little known that it is found written in every way; Mersthel, Herthel, Hermstel, Horochelle, &c. Nevertheless, the discovery of a new comet was an event important enough to induce a study of the new body. Laplace, Méchain, Boscowich, and Lexell, endeavoured to determine the orbit along which it moved. Many months elapsed before they guessed that it was a real planet; and it was not until after having observed that all the imagined orbits for the pretended comet were soon contradicted by observation, and that it probably had a circular orbit, much more distant from the Sun than Saturn, until then the boundary of the system, that they agreed to regard it as a planet. Still this was but a provisional agreement.

It was, indeed, more difficult than was thought thus to increase unscrupulously the family of the Sun. Many reasons of propriety were opposed to it. Old ideas are tyrannical. It had been the custom for so long to regard the venerable Saturn as keeper of the frontiers, that it required a great effort to determine upon withdrawing these frontiers, and guarding them by a new world. It happened in this as in the discovery of the small planets situated between Mars and Jupiter. Two years before this discovery was made, Kepler imagined, for the harmony of the world, a large planet in this space, and the most frivolous and senseless considerations were urged against it. For instance, they reasoned: 'There are only seven openings in the head, the two eyes, the two ears, the two nostrils, and the mouth: there are only seven metals, there are but seven days in the week; therefore there are but seven planets,' &c. Considerations like these, and others no less imaginary, often hinder the progress of astronomy.

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* 'If Herschel had directed his telescope towards the constellation of the Twins eleven days sooner,' said Arago, 'the real movement of Uranus would have escaped him, for this planet was on the second at one of its stationary points.' It may be seen by this remark on what the greatest astronomical discoveries depend.

When William Herschel, having been present as a spectator at the debates created by his discovery, came to the belief that his comet was a planet situated at the confines of our system, he claimed the right, which was indisputably his, of christening the new star. Animated by a lawful motive of gratitude towards George III., who had appreciated his astronomical worth and given him an annual pension, he at first proposed the name of Georgium Sidus, George's star, as Galileo had called the satellites of Jupiter discovered by him, the Medici's stars, and as Horace had said, Julium Sidus.

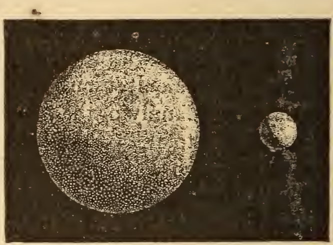

Fig. 35. Uranus.

Others proposed the name of Neptune, in order to preserve the mythological character; Saturn would be thus found between his two sons, Jupiter and Neptune. Others added to Neptune the name of George III.; others again proposed Astræa, considering the goddess of Justice was as far as possible from the Earth: Cybele, mother of the gods; Uranus, the most ancient of all to whom reparation was due after so many hundred years of neglect. Lalande suggested Herschel's name to immortalise the discoverer. These two denominations prevailed. For a long time the planet bore the name of Herschel, but custom has since declared for the mythological appellation of Uranus.

The discovery of Uranus has increased the radius of the solar system from 872 millions of miles to 1753 millions.

Compared with the preceding, this planet is not very large, for it is scarcely eighty-two times more bulky than the Earth. Its seasons last twenty-one years, and its years eighty-four years and a quarter. Around it revolve eight satellites, six of which Herschel himself discovered. These eight moons are rather curious, for instead of revolving from west to east like all moons and planets of the system, they go from east to west, and moreover, travel at a singularly decided inclination. The reason of this, no one can tell.

It was thus, at the period when European society felt the first miseries of the Revolution which was near, that Science with peaceful conquests saw its glory increase, and visited new skies.

# X.

## NEPTUNE.

> 'Hence the view is profound;
> It floats between the world
> And the depths of the sky.'
> GOETHE.

THE world which here marks the frontiers of the system, is situated at such a distance from the Sun, that the light and heat which it receives from it are thirteen hundred times less than that with which the Earth is enriched, so that no great difference can be noticed between the day and night of this distant planet, and to it the solar disk is nearly reduced to the smallness of the stars. Hence it follows that at its surface the stars of the heavens remain visible in the day as well as in the night, and that the Sun is only a more brilliant star than the others. From Neptune, then, the eye, situated between the planetary world and the starry heavens, is in a region where it must be much more sensitive and endowed with peculiar properties, which permit it to especially appreciate the sidereal world and its riches.

2746 millions of miles is the distance which separates this world from the Sun. Until the time of its discovery, the frontiers of the planetary system already augmented by the addition of Uranus, were confined to an orbit of 1753 millions of miles in radius. Does this, then, imply that these are the utmost limits, and that analysis will not be able to go further and add fresh members to the already increasing family of the Sun? No. When observations spreading over a long series of years shall have been made, and compared with each other, the universal law of gravitation by which the existence of this planet was known before ever being perceived in the field of the telescope, will prove the existence of others if others exist, which is probable; and the progress of optics following equally the progress of astronomy will give to the visual power, again magnified, the power to discover such distant planets which will, doubtless, be of the sixteenth or seventeenth magnitude.

Imagine a body a hundred times larger than the Earth carried into the gloomy deserts of space to the distance of the Neptunian orbit. It floats, isolated, in the obscurity of space, following an immense but purely ideal curve, and which exists only in theory in the decree of eternal laws. It follows this curve, and revolves on itself without ever deviating from its path. To finish its immense route and return to its starting-point, it requires 164 years. It will return and again pass through this mysterious point of space, which it passed nearly two centuries before. What power moves it? What hand guides this blind body through the night of the distant regions, and what causes it to describe this harmonious curve? It is universal attraction.

Instead of following a regular ellipse round the Sun, the planet Uranus underwent, from some unknown cause, a perturbation, which retarded its theoretical path, and extended its circular curve towards a certain point, as if an attractive cause had seduced the traveller from its path, and had made it deviate from its proposed route. It was calculated that, in order to produce at this point an attraction of such intensity, it was necessary that there should be on that side of the system beyond Uranus, a planet of a certain mass, and at a certain distance. Two astronomers, the one French, the other English, set to work at the same time in this research. They discovered the disturbing cause theoretically, and observers directed their telescopes to the spot thus indicated by theory. They were not long in actually discovering the body near the spot pointed out, and they were able to announce to the world the most brilliant confirmation of universal gravitation.

The distance of this planet had been theoretically deduced from a well-known empirical law called 'Bode's Law,' which, however, was first given out by Titius. It is as follows. Starting from 0 put down the number 3 and double successively thus :—

0 3 6 12 24 48 96 192 384.

Add four to each of these numbers :—

4 7 10 16 28 52 100 196 388.

Now, it happens that these numbers represent the successive distances of the planets from the Sun, even of the small planets which were not known at the time this law was promulgated for the first time. The orbit of Mercury is expressed by the number 4 ; that of Venus by 7 ; the Earth by 10; Mars by 16. 28 describes the mean orbit of the asteroids. Jupiter's is expressed by 52 ; Saturn's by 100 ; and Uranus' by 196. According to this there seemed a legitimate right to place the new planet at the distance of 388. Now, the real distance of Neptune is only 300; and it is to this irregularity of the series starting from Uranus that we must attribute the disagreement which exists in reality between the elements of the theoretical prediction of Neptune and those given by ulterior observation.

It must be remembered that this formula is not, like that of attraction, the expression of the intimate force which governs the spheres. After Kepler had recognised the three fundamental laws which we have before announced, Newton discovered the mode of action of this universal force, to which we owe the stability of the world. 'Bodies attract each other according to their masses and in the inverse ratio of the square of their distances.' In the immensity of the vast heavens, the gigantic suns of space obey this formula, and in the littleness of the actions which are performed on the surface of the Earth, the mechanical functions of small beings do not escape its rule. It is the law of creation, sustaining the life of the edifice in the invisible as in the vast. 'Attraction,' says the author of 'Paul and Virginia,' 'is a harmonious lyre, which resounds under divine fingers.'

When we contemplate these harmonious movements of the spheres in their orbits, in the system confided to the keeping of the Sun; when we have seen that these formidable laws regulate the movements of stellar systems with the same sovereignty as they direct those which are executed around us, and when to this marvellous grandeur of the laws of nature, we compare human weakness and our insignificance in the midst of this sublime creation, we sincerely admire the genius of the men which rose to the idea of these causes: it seems that their power spreads itself to other men, and one feels proud of belonging to humanity.

The beautiful verses of Delille's are worthy of Newton:—

'Pénétrez de Newton l'auguste sanctuaire;
Loin d'un monde frivole et de son vain fracas,
De tous les vils mortels qui rampent ici-bas,
Dans cette vaste mer de feux étincelants
Devant qui notre esprit recule d'épouvante,
Newton plonge; il poursuit, il atteint ces grands corps,
Qui, jusqu'à lui, sans lois, sans règle et sans accords,
Roulaient désordonnés sous les voûtes profondes.
De ce brillant chaos, Newton a fait des mondes.
Atlas de tous ces yeux qui reposent sur lui,
Il se fait l'un de l'autre et la règle et l'appui:
Il fixe leurs grandeurs, leurs masses, leurs distances,
C'est en vain qu'égarée en ces déserts immenses
La comète espérait échapper à ses yeux:
Fixes ou vagabonds, il poursuit tous ces feux,
Qui suivent de leur cours l'incroyable vitesse.
Sans cesse s'attirant, se repoussant sans cesse.

Et par deux mouvements, mais par la même loi,
Roulent tous l'un sur l'autre, et chacun d'eux sur soi.
O pouvoir du génie et d'une âme divine!
Ce que Dieu seul a fait, Newton seul l'imagine ;
Et chaque astre répète en proclamant leur nom :
Gloire au Dieu qui créa les mondes et Newton !

# XI.

## COMETS.

> 'Je viens vous annoncer une grande nouvelle :
> Nous l'avons, en dormant, madame, échappé belle.
> Un monde près de nous a passé tout du long,
> Est chu tout au travers de notre tourbillon ;
> Et s'il eût en chemin rencontré notre terre,
> Elle eût été brisée en morceaux comme verre.'
>
> Molière.

This announcement of Trissotin's to Philaminte, who begins the parody on the fears caused by the appearance of comets, would not have been a parody four or five centuries ago. These tailed bodies, which suddenly come to light up the heavens, were for long regarded with terror, like so many warning signs of divine wrath. Men have always thought themselves much more important than they really are in the universal order ; they have had the vanity to pretend that the whole creation was made for them, whilst in reality the whole creation does not suspect their existence. The Earth we inhabit is only one of the smallest worlds ; and therefore it can scarcely be for it alone that all the wonders of the heavens, of which the immense majority remains hidden from it, were created. In this disposition of man to see in himself the centre and the end of everything, it was easy indeed to consider the steps of nature as unfolded in his favour ; and if some unusual phenomenon presented itself, it was considered to be without doubt a warning from Heaven. If these illusions had had no other result than the amelioration of the more timorous of the community one would regret those ages of ignorance; but not only were these fancied warnings of no use, seeing that once the danger passed, man returned to his former state; but they also kept up among people imaginary terrors, and revived the fatal resolutions caused by the fear of the end of the world.

When one fancies the world is about to end,—and this has been believed for more than a thousand years,—no solicitude is felt in the work of improving this world; and, by the indifference or disdain into which one falls, periods of famine and general misery are induced which at certain times have overtaken our community. Why use the wealth of a world which is going to perish? Why work, be instructed, or rise in the progress of the sciences or arts? Much better to forget the world, and absorb oneself in the barren contemplation of an unknown life. It is thus that ages of ignorance weigh on man, and thrust him further and further into darkness, while Science makes known by its influence on the whole community, its great value, and the magnitude of its aim.

The history of a comet would be an instructive episode of the great history of the heavens. In it could be brought together the description of the progressive movement of human thought, as well as the astronomical theory of these extraordinary bodies. Let us take, for example, one of the most memorable and best-known comets, and give an outline of its successive passages near the Earth. Like the planetary worlds, Comets belong to the solar system, and are subject to the rule of the Star King. It is the universal law of gravitation which guides their path; solar attraction governs them, as it governs the movement of the planets and the small satellites. The chief point of difference between them and the planets is, that their orbits are very elongated; and, instead of being nearly circular, they take the elliptical form. In consequence of the nature of these orbits, the same comet may approach very near the Sun, and afterwards travel from it to immense distances. Thus, the period of the Comet of 1680 has been estimated at 3000 years. It approaches the Sun, so as to be nearer to it than our Moon is to us, whilst it recedes to a distance 853 times greater than the distance of the Earth from the Sun. On the 17th of December, 1680, it was at its perihelion—that is, at its greatest proximity to the Sun; it is now continuing its path beyond the Neptunian orbit. Its velocity varies according to its distance from the solar body. At its perihelion it travels thousands of leagues per minute; at its aphelion it does not pass over more than a few yards. Its proximity to the Sun in its passage near that body caused Newton to think that it received a heat 28,000 greater than that we experience at the summer solstice; and that this heat being 2000 times greater than that of red-hot iron, an iron globe of the same dimensions would be 50,000 years entirely losing its heat. Newton added that in the end comets will approach so near the Sun that they will not be able to escape the preponderance of its attraction, and that they will fall one after the other into this brilliant body, thus keeping up the heat which it perpetually pours out into space. Such is the deplorable end assigned to comets by the author

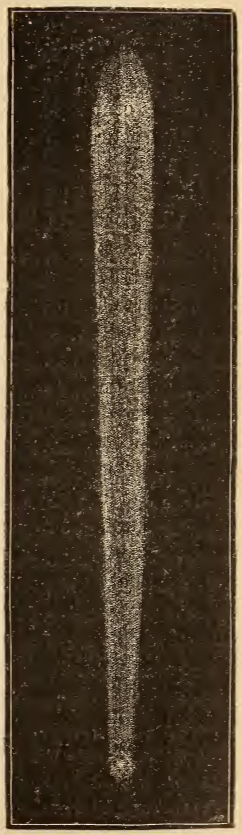
Fig. 36. Comet of 1680.

of the 'Principia,' an end which makes De la Bretonne say to Rétif: 'An immense comet, already larger than Jupiter, was again increased in its path by being blended with six other dying comets. Thus displaced from its ordinary route by these slight shocks, it did not pursue its true elliptical orbit; so that the unfortunate thing was precipitated into the devouring centre of the Sun.' 'It is said,' added he, 'that the poor comet, thus burned alive, sent forth dreadful cries!'

It will be interesting, then, in a double point of view, to follow a comet in its different passages in sight of the Earth. Let us take the most important in astronomical history—the one whose orbit has been calculated by Edmund Halley, and which was named after him. It was in 1682 that this comet appeared in its greatest brilliancy, accompanied with a tail which did not measure less than 32 millions of miles. By the observation of the path which it described in the heavens, and the time it occupied in describing it, this astronomer calculated its orbit, and recognised that the comet was the same as that which was admired in 1531 and 1607, and which ought to have reappeared in 1759. Never did scientific prediction excite a more lively interest. The comet returned at the appointed time; and on the 12th of March, 1759, reached its perihelion. Since the year 12 before the Christian era, it had presented itself twenty-four times to the Earth. It was principally from the astronomical annals of China that it was possible to follow it up to this period.

Its first memorable appearance in the history of France is that of 837, in the reign of Louis le Débonnaire. An anonymous writer of chronicles of that time, named 'The Astronomer,' gave the following details of this appearance, relative to the influence of the comet on the imperial imagination:

'During the holy days of the solemnization of Easter, a phenomenon ever fatal, and of gloomy foreboding, appeared in the heavens. As soon as the Emperor, who paid attention to these phenomena, received the first announcement of it, he gave himself no rest until he had called a certain learned man and myself before him. As soon as I arrived, he anxiously asked me what I thought of such a sign; I asked time of him, in order to consider the aspect of the stars, and to discover the truth by their means, promising to acquaint him on the morrow; but the Emperor, persuaded that I wished to gain time, which was true, in order not to be obliged to announce anything fatal to him, said to me: "Go on the terrace of the palace and return at once to tell me what you have seen, for I did not see this star last evening, and you did not point it out to me; but I know that it is a comet; tell me what you think it announces to me." Then scarcely allowing me time to say a word, he added: "There is still another thing you keep back: it is that a change of reign and the death of a prince are announced by this sign." And as I advanced the testimony of the prophet, who said: "Fear not the signs of the heavens as the nations fear them," the prince with his grand nature, and the wisdom which never forsook him, said, "We must only fear Him who has created both us and this star. But as this phenomenon may refer to us, let us acknowledge it as a warning from Heaven."'

Louis le Debonnaire gave himself and his court to fasting and prayer, and built churches and monasteries. He died three years later, in 840, and historians have profited by this slight coincidence to prove that the appearance of the comet was a harbinger of death. The historian, Raoul Glaber, added later: 'These phenomena of the universe are never presented to man without surely announcing some wonderful and terrible event.'

Halley's comet again appeared in April 1066, at the moment when William the Conqueror invaded England. It was pretended that it had the greatest influence on the fate of the battle of Hastings, which delivered over the country to the Normans.

A contemporary poet, alluding probably to the English diadem with which William was crowned, had proclaimed in one place, 'that the comet had been more favourable to William than nature had been to Cæsar; the latter had no hair, but William had received some from the comet.' A monk of Malmesbury apostrophised the comet in these terms: 'Here thou art again, thou cause of the tears of many mothers! It is long since I have seen thee, but I see thee now, more terrible than ever; thou threatenest my country with complete ruin!'

In 1455, the same comet made a more memorable appearance still. The Turks and Christians were at war, the West and the East seemed armed from head to foot—on the point of annihilating each other. The crusade undertaken by Pope Calixtus III. against the invading Saracens, was waged with redoubled ardour on the sudden appearance of the star with the flaming tail. Mahomet II. took Constantinople by storm, and raised the siege of Belgrade. But the Pope having put aside both the curse of the comet and the abominable designs of the Mussulmans, the Christians gained the battle, and vanquished their enemies in a bloody fight. The *Angelus* to the sound of bells dates from these ordinances of Calixtus III. referring to the comet.

In his poem on astronomy, Daru, of the French Academy, describes this episode in eloquent terms:

'Un autre Mahomet a-t-il d'un bras puissant
Aux murs de Constantin arboré le croissant:
Le Danube étonné se trouble au bruit des armes,
La Grèce est dans les fers, l'Europe est en alarmes;
Et pour comble d'horreur, l'astre au visage ardent
De ses ailes de feu va couvrir l'Occident.
Au pied de ses autels, qu'il ne saurait défendre,
Calixte, l'œil en pleurs, le front couvert de cendre,
Conjure la comète, objet de tant d'effroi:
Regarde vers les cieux, pontife, et lève-toi!

> L'astre poursuit sa course, et le fer d'Huniade
> Arrête le vainqueur, qui tombe sous Belgrade.
> Dans les cieux cependant le globe suspendu,
> Par la loi générale à jamais retenu,
> Ignore les terreurs, l'existence de Rome,
> Et la Terre peut-être, et jusqu'au nom de l'homme,
> De l'homme, être crédule, atome ambitieux,
> Qui tremble sons un prêtre et qui lit dans les cieux.'

This ancient comet witnessed many revolutions in human history, at each of its appearances, even in its later ones, in 1682, 1759, 1835, it was also presented to the Earth under the most diverse aspects, passing through a great variety of forms, from the appearance of a curved sabre, as in 1456, to that of a misty head, as in its last visit. Moreover, this is not an exception to the general rule, for these mysterious stars have had the gift of exercising a power on the imagination which plunged it in ecstasy or trouble. Swords of fire, bloody crosses, flaming daggers, spears, dragons, fish, and other appearances of the same kind, were given to them in the middle ages and the Renaissance.

Comets like those of 1577 appear, moreover, to justify by their strange form the titles with which they are generally greeted. The most serious writers were not free from this terror. Thus, in a chapter on celestial monsters, the celebrated surgeon, Ambroise Paré, described the comet of 1528 under the most vivid and frightful colours: 'This comet was so horrible and dreadful that it engendered such great terror to the people, that they died, some with fear, others with illness. It appeared to be of immense length, and of blood colour; at its head was seen the figure of a curved arm, holding a large sword in the hand as if it wished to strike. At the point of the sword there were three stars, and on either side were seen a great number of hatchets, knives, and swords covered with blood, amongst which were numerous hideous human faces, with bristling beards and hair.'

The imagination has good eyes when it exerts itself. The great and strange variety of cometary aspects is described with exactitude by Father Souciet in his Latin poem on comets. 'Most of them,' says he, 'shine with fires interlaced like thick hair, and from this they have taken the name of comets. One draws after it the twisted folds of a long tail; another appears to have a white and bushy beard; this one throws a glimmer similar to that of a lamp burning during the night; that one, O Titan! represents thy resplendent face; and this other, O Phebe! the form of thy nascent horns. There are some which bristle with twisted serpents. Shall I speak of those armies which have sometimes appeared in the air? of those clouds which follow as it were along a circle, or which resembled the head of Medusa? Have there not often been seen figures of men or savage animals?

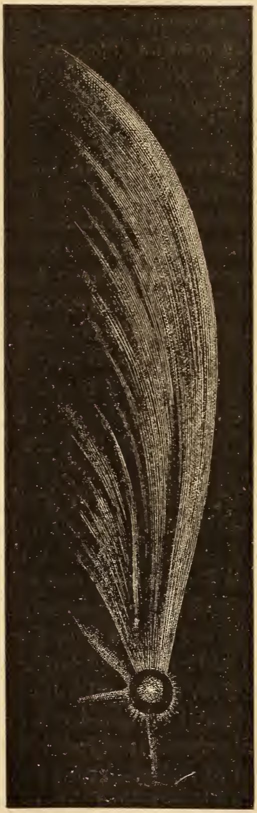

Fig. 39. Comet of 1577.

Often, in the gloom of night, lighted up by these sad fires, the horrible sound of arms is heard, the clashing of swords which meet in the clouds, the ether furiously resounding with fearful din which crush the people with terror. All comets have a melancholy light, but they have not all the same colour. Some have a leaden colour; others that of flame or brass. The fires of some have the redness of blood; others resemble the brightness of silver.

Some again are azure; others have the dark and pale colour of iron. These differences come from the diversity of the vapours which surround them, or from the different manner in which they receive the Sun's rays. Do you not see in our fires, that various kinds of wood produce different colours? Pines and firs give a flame mixed with thick smoke, and throw out little light. That which rises from sulphur and thick bitumen is bluish. Lighted straw gives out sparks of a reddish colour. The large olive, laurel, ash of Parnassus, &c., trees which always retain their sap, throw a whitish light similar to that of a lamp. Thus, comets whose fires are formed of different materials, each take and preserve a colour which is peculiar to them.'

Instead of being a cause of fear and terror, the variety and variability of the aspect of comets ought rather to indicate to us the harmlessness of their nature.

# XII.

## COMETS.—(CONTINUED.)

'Ces astres, après avoir été si longtemps la terreur du monde, sont tombés tout à coup dans un tel discrédit, qu'on ne les croit plus capables de causer que des rhumes.'

MAUPERTUIS.

THESE are the expressions of the geometer to whom we owe some of the first measurements relative to the figure of the Earth. The following are some of the ideas put forth in his 'Lettres sur la Comete de 1742:'—

In the present day, it will not be believed that such distant bodies as comets can have any influence on things here below, nor can they be signs of what is to happen. What connexion should these bodies have with that which goes on in the councils and armies of kings?

It would be necessary that their influence should be made known, either by revelation, reason, or experience; and it may be said that we have not met with it in any of these sources of our knowledge. It is very true that there is an universal connexion between everything in nature, as much in the physical as in the moral world; each event, bound to that which precedes it, and to that which follows it, is only one link of the chain which forms the order and succession of things; if it were not placed as it is, the chain would be different, and would belong to another universe.

Reasoning thus, the astronomer doubts the non-influence of comets as well as he does their influence; to confirm his ideas, he recalls those of others, and soon comes to the belief that comets cause many other events besides simple colds.

Kepler, to whom astronomy owes so much, thought it reasonable that, as the sea has its whales and its monsters, the air possesses them also. These monsters are comets, and he explains how they are produced.

Some people have believed that comets were expressly created every time it was necessary to announce the design of God to men, and that the angels had the care of them. They added that this explanation solved all the difficulties which could arise in the matter. Lastly, in order that all the absurdities with regard to them may be stated, there were some people who denied that comets existed, and who considered them as false appearances, caused by the reflexion or refraction of light. They alone understood how the reflexion or refraction was caused, without bodies to cause it. According to Aristotle, comets were meteors formed by exhalations from the earth and sea, and this was, as may be imagined, the decision of the crowd of philosophers who believed and thought only as he did. In older times still, people possessed more correct ideas of comets. The Chaldeans knew that they were material bodies and a species of planet, the courses of which they succeeded in calculating. Seneca embraced this opinion; he speaks to us of comets in a manner so conformable with all that is known of them in the present day, that it may be said that he guessed what the experience and observations of moderns have discovered.

It was after having spoken of the opinions of the ancients that Maupertuis explained his own. 'The regular course of comets no longer allows them to be considered as warnings, or as lighted torches to terrify the Earth. But although a more perfect knowledge than that which the ancients had, prevents us from regarding them as supernatural warnings, it teaches us that they may be the physical causes of great events.' He dreads the approach of the tailed bodies to the Earth. In the variety of their movements, he sees the possibility of an encounter with some planets, and, consequently, with the Earth. It cannot then be doubted, says he, that terrible accidents will happen from the simple approach of these two bodies, for such approach would make great changes in their movements, either because of the attraction which they exercise over each other, or because of some fluid confined between them. The least of these movements would do nothing less than change the situation of the axis and poles of the Earth. That part of the globe which was formerly towards the equator, would be found, after such an event, near the poles, and that which was near the poles would be found towards the equator. 'The approach of a comet,' he adds, 'might have other still more frightful consequences. I have not yet spoken to you of the tails of comets. On these, as on comets, strange opinions have been held; but the most probable, is, that they are principally composed of immense torrents of exhalations and vapours, which the Sun's heat draws from their nuclei. A comet, accompanied by a tail, may pass so near the Earth, that we may find ourselves immersed in the torrent which it carries with it.'

Such is the perspective to which we are by degrees conducted by this physicist; but he gives us a singular consolation. As the human race would all perish together in this catastrophe, being swallowed up by boiling water, or poisoned by mephitic gases, and as no one would remain to weep over the agony of the Earth, he tells us it is easy to console ourselves. 'A universal misfortune is scarcely a misfortune. It would be he whose unfortunately too-robust temperament would make him survive alone in an accident which had destroyed the whole human race except himself, who would have to lament! King of the whole Earth, possessor of all its treasures; he would perish of sadness and ennui: his whole life would not be worth the last moment of him who dies with those he loves.'

Thus, in the last century, people still believed in the terrible power of these unhappy stars. In the present day, and especially since the famous comet of 1811, country people have imagined rather that they predicted excellent vintages. These ideas are as void of proof as the former. Although these bodies have greatly lost their prestige, they have not been entirely despoiled of it. Moreover, who could efface the impression produced by some of their aspects? Often they have been considered as signs of curses hovering over men and empires. Such is the lamentation of Byron in 'Manfred,' to whom the seventh spirit addresses the following words:—

'The star which rules thy destiny
Was ruled, ere earth began, by me:
It was a world as fresh and fair
As e'er revolved round sun in air:
Its course was free and regular,
Space bosom'd not a lovelier star.
The hour arrived—and it became
A wandering mass of shapeless flame,
A pathless comet, and a curse,
The menace of the universe;
Still rolling on with innate force,
Without a sphere, without a course,
A bright deformity on high,
The monster of the upper sky!'

Nevertheless, nothing proves that comets are gifted with any influence whatever, I do not say on the morals of men, but on the physics of the world. Their lightness, the extreme diffusion of their substance, induces us to believe rather that they possess no kind of action on the planets. Let us imagine that they are harmless. Like atmospheric clouds, whose magnitude, form, and shade, vary with the caprice of the winds and according to the fortuitous play of solar rays, the vaporous agglomerations which form comets, take every possible form under the impulsion of cosmical forces more or less intense. At their approach to the fiery body, their substance distends itself, assumes a wonderful size, and developes itself over an expanse of many million leagues. They are of such lightness and suppleness that a ray of heat may, at its will, cause them to take any shape: you have an instance of this lightness in the comet recently observed in 1862; the form and position of the luminous appendages changed from day to day; and observers might have

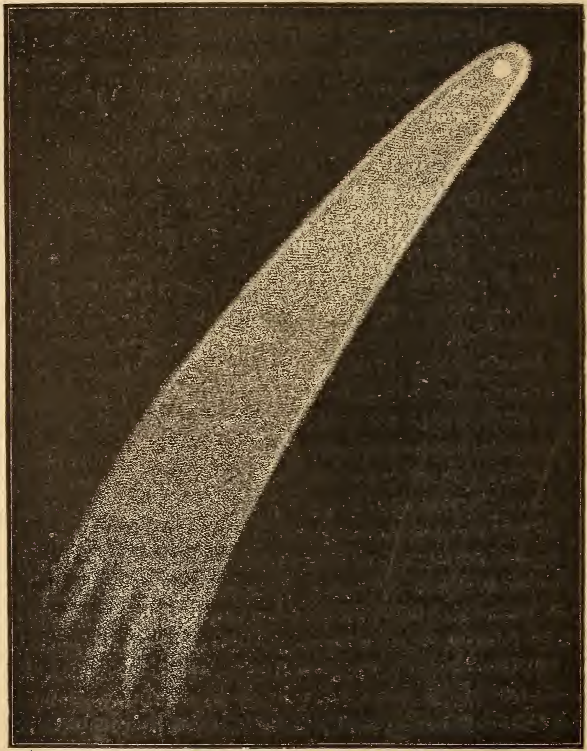

Fig. 39. Comet of 1811.

believed that even a portion of the substance of the nucleus flowed into space. On the other hand, their rarity is such, that out of the tails of certain comets we should be able to cut a piece the size of Notre Dame, and inhale it as a homœopathic inspiration. Comets have been seen several million leagues long, whose mass was, nevertheless, so small that it would have been possible, without fatigue, to carry it on one's shoulder. Thus, the extreme variability of the cometary forms ought to proclaim these terrible bodies harmless; and we may say with the friend of the Marquis du Châtelet these words which represent, at the same time, the nature of the movement of these bodies:—

> ‘Comètes, que l'on craint à l'égal du tonnerre,
> Cessez d'épouvanter les peuples de la Terre:
> Dans une ellipse immense achevez votre cours;
> Remontez, descendez près de l'astre des jours;
> Lancez vos feux, volez, et revenant sans cesse,
> Des mondes épuisés ranimez la vieillesse.’

And, indeed, these celestial bodies are not exceptional phenomena; they are subjected, like others, to the inexorable laws of nature. Two thousand years ago, Seneca wrote, ‘A day will come when the course of these bodies will be known, and submitted to rules, like that of the planets.’ The prophecy of the philosopher is realised. It is now known that, like the planets, comets gravitate round the Sun, and depend equally on its central attraction. Only, instead of moving in orbits, circular, or nearly so, they describe oval curves—very long ellipses. This is the great distinction established between them and planets. Instead of being opaque, heavy, and important bodies like our planets, they are of great lightness, and extreme tenuity. One day, a comet carried away by its rapid march, traversed the system of Jupiter; the satellites and the planet were for some hours surrounded by the comet; and when the body had passed over them, they had not undergone the slightest deviation in their path. When Maupertuis, wishing to explain the origin of Saturn's ring, thought he had conceived an ingenious idea in attributing this appendage to the tail of a comet which was wound

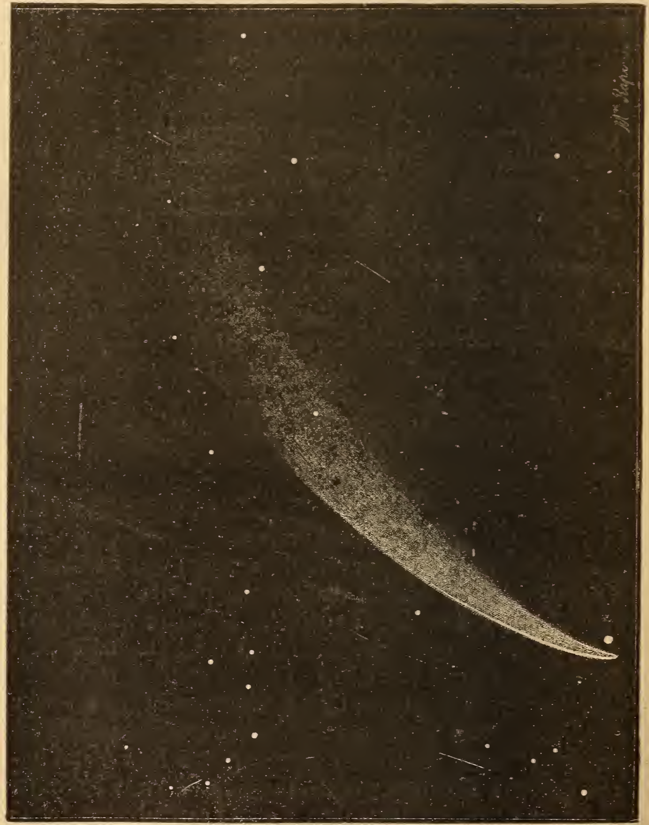

Fig. 42 —Donati's Comet.

round the planet, he did not dream of the extreme rarity of these impotent vapours.

The distinctive character of comets lies especially in the length of their course, and in the immense duration of their journeys round the Sun, through the celestial regions.

The following lines are by the poet Conder:—

'Mysterious visitant, whose beauteous light
Among the wondering stars so strangely gleams!
Like a proud banner in the train of night,
Th' emblazon'd flag of Deity it streams—
Infinity is written on thy beams;
And thought in vain would through the pathless sky
Explore thy secret course. Thy circle seems
Too vast for Time to grasp. Oh, can that eye
Which numbers hosts like thee, this atom earth descry?'

# BOOK IV.

## I.

## THE TERRESTRIAL GLOBE.

> 'La terre, nuit et jour à sa marche fidèle,
> Emporte Galilée et son juge avec elle.'
>
> RACINE FILS.

WHILE reviewing the worlds belonging to solar rule, we passed over the space which separates Venus from Mars, without noticing a body which occupies the mid-distance. This body, moreover, ought to interest us somewhat, for it relates to us more nearly than all the others.

The Earth, isolated in space like all the other planets that we have seen, is situated some 91 millions of miles from the Sun, and journeys along an orbit which it traverses in 365¼ days. Like some of its companions, it has a faithful attendant—a satellite revolving round it. This is its little system, and the Moon accompanies it humbly in all its voyages through space.

Like the other planets, also, it rotates on an axis with great rapidity, for at some parts of its surface bodies travel at the rate of 1000 miles an hour. It is spheroidal, and rather flattened at its poles, which proves its primitive state of fluidity. Of this state, a proof more easy to recognise still remains in its volcanoes, with their open craters, from which are ejected the interior substances of the Earth in the state of fusion and at the high temperature, in which they exist at the present time. Correctly speaking, the whole Earth is still a globe of liquid substances, melted by the intense heat which glows under our feet; for the solid stratum of this globe—the crust which surrounds it, and on which we live, is not, it has been estimated, a hundred miles in thickness. The Earth resembles a thin glass globe, a yard in diameter, filled with metals in a state of fusion. If there were not some apertures—that is to say, some volcanoes, to allow the vapours to escape, it might happen that the globe would burst. What is the real size of this globe? Imagine a gigantic die, each side of which would measure one mile in length; you would have then a volume of one cubic mile. To form a volume equal to that of the Earth, it would be necessary to heap up 260,613 millions of these cubic miles.

What is its weight? We have already glanced at it in speaking of the Sun's weight. To express it in tons, it requires a row of twenty-two figures.

The weight of the atmosphere which surrounds the Earth, is not the millionth part of the weight of the whole Earth; yet each of us carries on our shoulders a pressure of about 8000 pounds. Let us add, in passing, that this pressure, although not to be despised, is not perceptible to us, because it is counter-balanced by an equal pressure exercised in the opposite direction by the fluids within our body.

The surface of the Earth is about 197,000,000 square miles. Of this surface, the ocean occupies 145,000,000 square miles; only 52,000,000 therefore remain for *terra firma*. There is then only about a quarter of the Earth's surface which is habitable; the remainder lies hidden in the bosom of the waves.

By retreating into space, we should be better able to judge of the Earth as a star. At the distance of the Moon, that is, about 240,000 miles, the Earth would appear to us as the Moon does, being not less luminous and much larger. At ten times this distance, the Earth would still present to the naked eye a perceptible disk, and its light would be intermediate between that of the Moon and that of the stars. Again, at ten times further, that is to say, at the distance of the orbit of Venus, the Earth would be seen under the form of a beautiful star of the first magnitude, without any appreciable disk, as a brilliant point, similar to Jupiter. But if we go further still, the Earth, already promoted from the rank of a planet to that of a star of the first magnitude, will afterwards fall from magnitude to magnitude to the last order of visibility, and would be finally lost in the depths of the invisible. It is scarcely necessary to add, that the light with which it shines and with which it is radiant in space is no other than the light received by us from the Sun, and it would be seen under every possible phase according as it would be observed fully lighted up, or from one side, or obliquely, or when turning round its opposite hemisphere to the Sun.

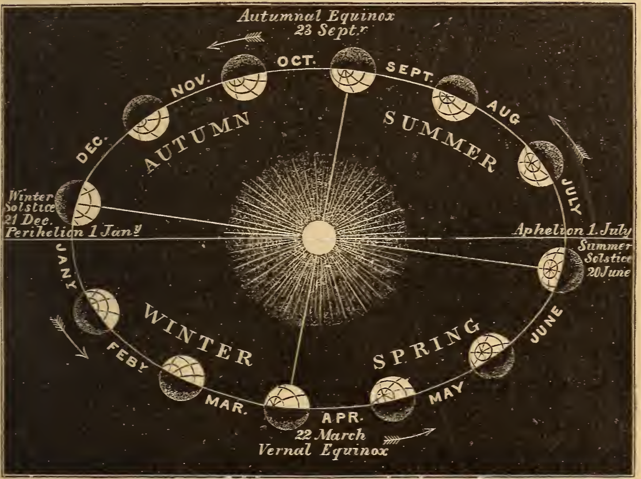
Autumnal Equinox
23 Sept.r
OCT.
NOV.
SEPT.
AUG
DEC.
AUTUMN
SUMMER
JULY
Winter Solstice
21 Dec.
Perihelion 1 Jan.y
Aphelion 1. July
Summer Solstice
20 June
JANY
WINTER
FEBY
SPRING
JUNE
MAY
MAR.
APR.
22 March
Vernal Equinox

Fig. 43.—Orbit of the Earth.

The Earth revolves round the Sun, with a movement of translation similar to that which we have noticed in the case of all the planets. It is this movement which constitutes its year. Its rotatory movement on its axis, which may be compared to that of a spinning top, constitutes its diurnal period,—its day. It is to this second movement that we owe the illusion of the apparent movement of all the stars.

All that has been said on the diurnal movement of the stars round the Pole Star, will be easily understood if we reflect that this star lies in the continuation of the axis of the Earth. The Earth turning, suppose, from left to right in our northern hemisphere, all the objects situated outside it, that is to say, the stars. appear to turn from right to left, in the direction contrary to the movement which carries us on. When you are in a railway carriage, if you forget the movement of the train, the objects you pass will appear to fly behind you, and if you did not know for certain that it was you who were moving, believing yourself stationary, you would have the conviction that it was the trees and hills which are travelling. A similar delusion presents itself when we find ourselves on the top of a high tower, and the clouds pass rapidly above us. It seems as if the tower advances and moves under our feet. One morning, I was at the top of the steeple of Strasburg Cathedral, the sun had scarcely risen, and some clouds coming from the Rhine had entirely hidden the town and the whole lower space from me. These cloud-bands were driven by an east wind and passed below me. In spite of the complete certainty that I naturally had of the stability of the high cathedral, it was impossible to keep in my mind the feeling of reality, but the delusion carrying it away, I believed myself again in the train—the cathedral certainly moved towards Germany. I closed my eyes, but the movement continued its action in my mind, and it was not until ten minutes after, when the Sun had lighted up the scene, and cleared away the vapours, that the roofs of Strasburg restored me to the reality. The apparent movement of revolution of the Sun round the Earth, which seems to be effected from east to west,—the opposite of the real movement of the Earth, from west to east,—constitutes our day and night. The moment at which the Sun attains the middle of its course, the culminating point, is that which divides the day into two equal parts. The opposite moment when the Sun is diametrically under our feet, marks the middle of the night. From this it is evident that our noon is the midnight of the people who live in the countries situated on the opposite side of the Earth, and that, conversely, when they have noon, we have midnight. The Sun then regulates time by passing over the heads of each of the nations which inhabit the globe. The civil day commences at midnight, and is composed of two periods: the morning, from midnight to noon; the afternoon, from noon to midnight. Astronomers do not follow this custom; they reckon their day from noon, and make of it one period, from 0 hour to 24 hours, which they count from noon to the following noon.

Let us now see how the Earth is studied, and by what means its different parts are recognised.

As the Earth is a sphere, the two points at the opposite extremities of the ideal axis around which it rotates are called the poles. If we trace, perpendicularly to this axis, a large circle at an equal distance from the two poles, which would cut the sphere into two equal portions, this circle is the equator. Now, the distance from the equator to the poles on each side of it is divided into ninety equal distances; these are degrees of latitude. Lastly, the great equatorial circle itself, or the entire circumference of the globe, is divided into 360 equal parts by other great circles passing through the poles, arranged on the sphere, like the slices of a melon; these are the meridians of longitude. There are, consequently, 180 in each half of the sphere, and ninety in each quarter. These names, longitude and latitude, date from a time when the terrestrial region, which had alone been measured, was supposed to be an oblong figure, the length of which extended in the direction of the equator, and the width in that of the meridians.

Degrees of latitude then are counted starting from the equator; either north or south, as far as the north pole or the south pole. The degrees of longitude cut them, and are counted from any point, being reckoned towards the east entirely round the globe. The line of the poles goes from north to south, or south to north, indifferently; the line of the equator goes from east to west, or from west to east. When we advance from the eastern to the western side, we do not change our latitude, but our longitude. If, for instance, we go from Paris to Vienna, we shall have made fifteen degrees of longitude towards the east. As the Earth is 24,000 miles in circumference, we see that each of the 360 divisions *of its equator* (in other words, each of the degrees of longitude) is equal to 69½ miles; this

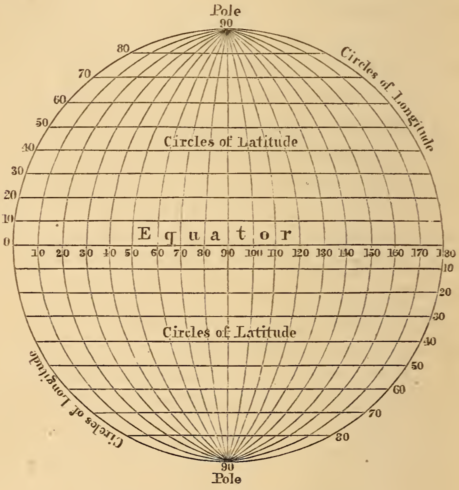
Pole
90
80
70
60
50
40
30
20
10
0
Circles of Longitude
Circles of Latitude
Equator
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
10
20
30
40
50
60
70
80
Circles of Latitude
Circles of Longitude
90
Pole

Fig. 44 —Divisions of the Globe.

value diminishes towards the poles. Moreover, as the Sun employs twenty-four hours for the journey it seems to make, it appears to travel 15 degrees an hour, 180 in twelve hours, and 360 in twenty-four hours; each hour being equivalent to 15 degrees. Thus, at Vienna, noon is an hour earlier than at Paris. Going on towards the east, the traveller will gain an hour every fifteen degrees, and if he keeps his watch according to London time, it will be an hour slow for every fifteen degrees. If he goes round the world travelling east, and if he sets his watch by the time of the countries through which he travels, it will advance on London time, in proportion as he continues his journey; when he arrives in London after having thus made the tour of the world easterly, he will have gained twenty-four hours, and will reckon a day more than we do: it will be Monday with him whilst with us it is Sunday.

It is on account of this difference in the time that if, on visiting the borders of the Rhine, you take the train at Kehl for Strasburg, as the Kehl station is regulated by the Baden time, and that of Strasburg by Paris time, you will arrive at Strasburg ten minutes before the time of your departure from Kehl.

For the same reason, when the Emperor of the French delivers his speech at the opening of the Chambers, this speech, flying to London by telegraph, the conclusion may be read by us before it has left the lips of the Emperor, reckoning merely by time. The watch of another traveller, going west, will be too fast, unlike our preceding one; and if he sets it by the time of the countries through which he passes, on returning to London, after having gone round the world with him it will only be Saturday, whilst with us it is Sunday. This singularity in the way of reckoning would be experienced every time a vessel arrived which had been round the world, if it had counted the days without conforming to the time of the countries through which it passed.

For the same reason, says Lalande ('Astronomie des

Dames'), the inhabitants of the South Sea Islands, which are twelve hours distant from our meridian, must see that travellers who come from the Indies, and those from America, count the days of the week differently, the first being one day in advance of the others; for, supposing that it is Sunday at noon at London, those who are in India say that Sunday noon has already passed six or seven hours; and in America it will still be Saturday evening. This fact appeared very singular to our old travellers, who were accused at first of having made a mistake in their almanac, and of having lost the thread of their calculation. Dampier, on going westwards to Mendanao, found that there they were a day in advance of him. Varenius said the same at Macao, a maritime town in China. The Portuguese always reckon a day in advance of the Spaniards at the Philippines, although not so distant; the former have Sunday, while the latter only count Saturday. The reason of this is, that the Portuguese who settled at Macao, went there by the Cape of Good Hope, travelling from the west—that is to say, starting from America, and crossing the South Sea.

It will be seen from this sketch that the Earth is a planet, and is regulated by planetary movements; that there is nothing absolute in any of these data of time and space; that all is relative to the condition of each planet; and that on each of the planets these elements differ according to their magnitude, as do the movements which give rise to them. But, it may be asked, on what grounds are these theoretical rules established, and what proves to us that, on the other hand, the Earth is not the absolute fixed world, established as the base of the heavens, and that all these movements are not real as they appear? How can it be proved that this is delusion of our senses; and, since it has been discovered only through observation, how has it been known that these are only simple appearances?

If you will listen to me for a few moments, you will be as convinced on this subject as I am.

## II.

## PROOFS THAT THE EARTH IS ROUND—THAT IT TURNS ON AN AXIS, AND REVOLVES ROUND THE SUN.

I HAVE known people who were never so eager as when addressing a thousand astronomical questions to me, and who had no sooner received my answers than they ridiculed all with the greatest ingenuity. Without noticing their really primitive rudeness, it was astonishing to see them, at the same time, so curious and yet so difficult to please. In their eyes scientific men were dreamers, who fancied they understood, but who, in reality, were as unable as the rest of the world to discover the secrets of nature.

I have known others, a little more intelligent than the former, but who, considering the different phases of the history of the science, its successes and its reverses, thought that we turn in a vicious circle, that we do not possess the true knowledge of things, and that our systems, however solidly based they may appear, must never be received but as hypotheses.

The cosmographical question which touches us most nearly, that of the isolation and movement of the Earth in space, especially dissipates the doubts of which I speak. For those who have heard these doubts stated, and who have not always undeniable proofs ready to hand, I shall give here the fundamental points on which this element of the new system of the world rests. We state, first, that the Earth is round; that it has the form of a sphere rather flattened at the poles. The first fact which bears testimony to this, is the convexity of the immense expanse of water which covers the greater part of the globe. The mere sight of a ship at sea suffices to prove this curvature. On reaching the blue line which seems to form the separation of the sky and the water, the receding ship, appears for a moment to rest on the horizon. A little later, it disappears, not the upper, but the lower part. The sea rises at first between the hull and the observer; afterwards it hides the lower sails; the tops of the masts are the last to disappear. A similar phenomenon is visible to an observer placed on the ship; the lower coasts vanish first; the buildings, high towers, and light-houses being the objects which remain longest visible. This double fact proves, in an evident manner, the convexity of the sea. If it were a plane surface, the distance alone would hide a vessel, and in this case all would disappear together, the upper as soon as the lower sails.

It follows, moreover, from this same kind of observation, that the curvature of the ocean is the same in every direction; now this property belongs only to the sphere.

The convexity of the sea extends itself to the solid land. In spite of the inequalities of the ground, the surface of the continents does not differ essentially from the seas; for it is known that the highest chains of mountains are far from producing, on the general surface of the Earth, protuberances comparable to the corrugations of the skin of an orange. Now, the rivers which divide the solid Earth in every direction, to be again united in the ocean, are scarcely higher than its level, and may be considered as the continued surface of the sea throughout the whole extent of the continents. The barometric measures of the heights of mountains have confirmed this fact. The land of the continents deviates little from this level, and presents, as a whole, a curvature entirely like that of the seas. Moreover, on the land as on the sea, the highest objects are always the first and last which the traveller sees.

Voyages of circumnavigation have, on the other hand, given a palpable proof of the sphericity of the Earth. The first of the navigators who undertook the daring enterprise of going round the world was the Portuguese, Magellan, who left Spain in 1519, going always to the West. Without having changed its direction, one of his vessels (that of Lieutenant Cano) reached Europe three years afterwards, as if it had come from the East. The numerous voyages of circumnavigation accomplished since that time have superabundantly confirmed this truth,—the Earth is round in every direction.

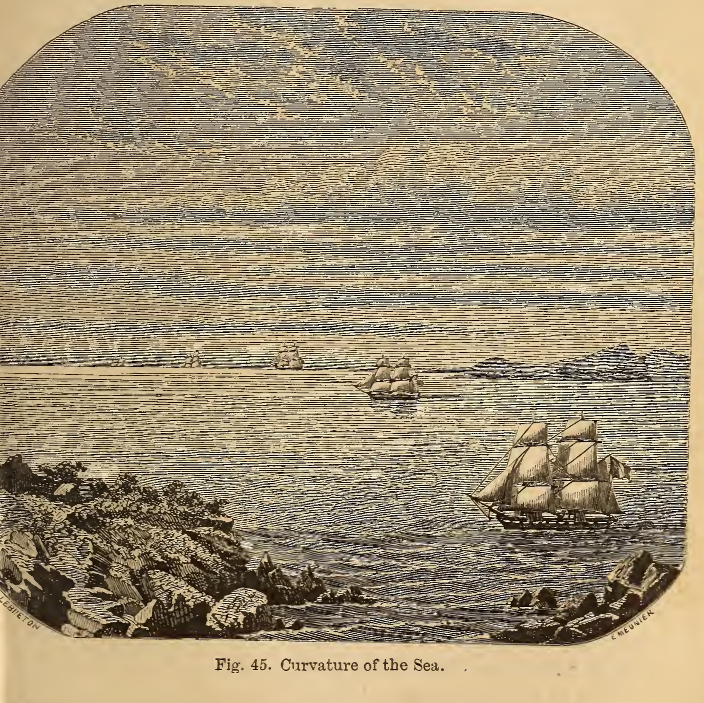

Fig. 45. Curvature of the Sea.

Another proof of the convexity of the Earth is furnished by the change of aspect undergone by the heavens during voyages. If we steer towards the pole or approach the equator, fresh stars are continually seen ; in the same way, those of the latitudes which we leave behind are lost to sight. This appearance can only be caused by the roundness of the Earth ; if the Earth were a plane, all the stars would be visible at the same time.

The shadow thrown by the Earth on the Moon, during eclipses, is always circular, whatever side the terrestrial disk at the time presents to the lunar disk. This conical shadow, invariably observed, is a fresh proof in favour of the sphericity of the Earth.

Such are the common facts which prove, in a positive way, the truth we have put forward. If we desired to enter into questions of geodesy or mechanics, I could present more rigorous considerations still ; but the preceding proofs are sufficient for us here.

Let us now see what basis of truth they have who assert that the Earth is isolated and in motion through space. The difficulty which certain minds have in believing that the Earth can be suspended like a balloon in space, and completely isolated from every kind of support, proceeds from a false notion of gravity. The history of ancient astronomy shows us the profound perplexity of the first observers who began to conceive the reality of this isolation, but could not understand what hindered this heavy globe, on which we live, from falling. The early Chaldeans supposed the Earth hollow, and similar to a boat ; it could then float on the abyss of the ether. Some ancients fancied that it rested on pivots placed at the two poles. Others supposed that it stretched indefinitely below our feet. All these systems were conceived under the impression of a false idea of gravity. To rid ourselves of this old delusion, it is necessary to know that gravity is only an effect produced by the attraction of a centre. A body never falls but when the attraction of another more important body solicits it. The expressions 'from above' and 'from below' can only be applied to a determined material system, in which the attractive centre may be considered as the bottom; beyond this they signify nothing. When, then, we suppose our globe isolated in space, we do nothing which can give rise to the objection before mentioned—namely, that the Earth will fall.

The Earth may be isolated in space. But not only may it, but it is so in reality. If it were supported by a neighbouring body at some point of its surface, this support which would necessarily be of very great dimensions, would certainly be perceived when it was approached. It would be seen projecting from the Earth, and losing itself in space. There is no necessity to state that travellers who have gone round the world in every direction have never perceived anything like this; the terrestrial surface is entirely detached from everything which exists around it. We now come to the third point of this chapter, to the positive proofs of the Earth's motion.

Let us notice, first, that the appearances of exterior objects will be identically the same to us whether the Earth being in repose these objects are in motion, or these objects being in repose the Earth itself is in motion. If the Earth carries in its movement everything which belongs to it, seas, atmosphere, clouds, &c., we should only be conscious of this movement, in which we participate, by the changing aspect of the immovable sky. Now, as in both cases, the appearances are the same, we are going to show that the hypothesis of the Earth's movement explains everything, whilst without it we fall into an inacceptable complication of systems.

If the Earth turns on its axis in twenty-four hours, we see directly that its mean radius being some 8000 miles, and its circumference 24,000, a point situated on the equator would travel 1000 miles an hour. This velocity, which seems considerable, has been thought to be an objection against the movement of the Earth. But we shall see with what tremendous velocity it would be necessary to animate the heavenly spheres to cause them each to traverse the circumference of the heavens in the same lapse of twenty-four hours.

In the first place, the Sun being distant from the Earth 23,000 times the terrestrial radius, on the hypothesis of the immobility of the Earth, the Sun would describe a circumference 23,000 times greater than the equator, that is, it would travel 23,000 times 1000 miles an hour!

Jupiter is about five times further away; its velocity would be more rapid still; Neptune, thirty times; it would travel still faster. Such would be the different velocities with which the planets would be animated if they revolved round our globe in twenty-four hours, as they appear to do. It shows that the objection against the movement of the Earth on the ground of rapid motion is untenable. What would this motion be if we should consider the fixed stars? Our neighbour, the star $\alpha$ of the Centaur, must travel more than a million times faster than 1000 miles an hour, and so on with all the stars, until with the more distant ones we should fail to find a number to express the velocity of their motion in revolving around this invisible point which we call the Earth.

Let us add to this, that these bodies are, one, 1400 times larger than the Earth, another, 1,400,000 times, and others more bulky still; that they are not united one to the other by any solid tie, which connects them with the movement of the heavenly vault; and that they are all situated at the most diverse distances; and this fearful complication of the system of the heavens will itself bear witness of its non-existence,—we might say of its mechanical impossibility.

But not only is it impossible for the diurnal movement of the celestial sphere to be understood, except by the admission of the movement of the Earth on its axis; but the movements of the planets in the zodiac, their stations and retrogradations, demand it as imperatively. To explain the planetary appearances supposing the Earth immovable, the ancients imagined as many as seventy circles placed one within the other, solid circles or crystal heavens which nothing could surpass in complication, and which if they could exist for an instant, would have soon been dashed to pieces by wandering comets or aerolites, which we meet in space.

Again, on the other hand, analogy singularly confirms the hypothesis of the movement of the Earth, and changes into certainty its great likelihood. The telescope shows in the planets, globes analogous to our own, which have a rotatory movement on their axes, a rotatory movement of twenty-four hours' duration in the case of the nearest planets, and of a less duration still in the case of the more distant ones. Thus, simplicity and analogy are in favour of the Earth's movement. Let us now add, that this movement is rigorously required and determined by all the laws of celestial mechanics. The great difficulty which has been advanced against the movement of the Earth, and which was in favour for some time, was this; if the Earth turns under our feet, if we raise ourselves up into space, and find the means of supporting ourselves for a few seconds or more, we ought to fall after this length of time on a spot more to the west than the starting-point. For instance, at the equator, he who could find means to support himself immovable in the atmosphere for half a minute, must fall some miles to the west of the place whence he started. This would be an excellent way of travelling, and Cyrano de Bergerac claimed to have used it when having raised himself in the atmosphere by a balloon of his own, he fell, a few hours after his departure, in Canada instead of coming down again into France. Some sentimentalists, Buchanan among the rest, have given to the objection a more tender form, saying that if the Earth revolved, the turtle-dove would never dare to rise from her nest, for soon she would inevitably lose sight of her young ones.

The reader has already replied to this objection by considering that all that belongs to the Earth participates, as we have stated, in its rotatory movement, and that to the last limits of the atmosphere our globe draws all in its course.

Direct observation of different phenomena has confirmed the theory of the movement of the Earth, and has confirmed it by undeniable material proofs.

If the globe turns, it developes a certain centrifugal force, this force will be *nil* at the poles, will have its maximum at the equator, and will be greater in proportion as the object to which it is applied is at a greater distance from the axis of rotation. This is on a large scale, similar to that which exists on a smaller one in the case of a string, or wheel in rapid movement. Now, let us suppose that we fix a plumb-line to the top of a tower, and allow the weight which stretches it to descend to the ground; the direction of this plumb-line towards the centre of the Earth, that is to say, the perpendicular to the water level, will be slightly modified by the effect of the centrifugal force, resulting from the rotation of the globe, measured at the foot of the tower. If we fix also at the top of the tower, a little to the east of the first, a second very short plumb-line, so that its weight is situated a little below the point of joining, this second line will not have quite the direction of the first, for the centrifugal force due to the movement of the Earth being greater at the top of the tower than at the foot, will cause the line to deviate a little to the east. This minute observation has been made and repeated with the greatest care; it is, in its way, a proof of the rotation of the Earth.

The oscillations of the seconds pendulum support the foregoing fact. Not only are they slower at the equator than at the poles, because the equatorial radius is greater than the polar radius, but the difference is too great to be attributed to this cause alone. At the equator, the centrifugal force partly counterbalances the effect of the weight. A curious remark to be made here is, that at the equator this force is $\frac{1}{289}$ of the weight. Now, as the force increases in proportion to the square of the velocity of rotation, and as 289 is the square of 17, if the Earth turned 17 times quicker, bodies at the equator would no longer weigh anything; a stone thrown into space would not fall.

Here is another fact no less positive than the preceding, and more easy to appreciate, as another proof in favour of the movement of the Earth. If the Earth were immovable, and the starry sphere revolved round it in twenty-four hours, the stars would never pass the meridian, would never rise or set, at the time predicted from their longitudes in the heavens. The luminous rays which they send to us, taking unequal intervals to reach us according to their relative distances, would cause an extreme confusion in the hours of their apparent passages. A star, for instance, which, in reality, passes now at the meridian, but is situated at such a distance that its light takes six hours to reach us, will only appear to pass it six hours later, that is to say, at the time of its setting. Another will be twelve hours late; another months or years, and so on. This is another material proof that it is not the heavenly spheres which move, but the Earth itself. The real annual movements of the stars in the heavens, of which we have spoken when stating the method used to determine the distances of the stars, furnish an equally positive proof of the movement of the Earth round the Sun. It is the same with the phenomenon of the aberration of light. The physics of the globe also furnish their contingent of proofs to the theory of the movement of the Earth; and it may be said that all branches of the sciences, nearly or distantly, connected with cosmography, are united in the unanimous confirmation of this theory. The very form of the terrestrial spheroid shows that this planet was a fluid mass animated with a certain velocity of rotation, a conclusion to which geologists have arrived in their researches. Other facts, as the currents of the atmosphere and the ocean, the polar currents and the trade-winds, equally find their cause in the rotation of the globe; but these facts have less value than the preceding ones, seeing that they might agree with the hypothesis of the movement of the Sun.

We shall conclude by recalling M. Foucault's brilliant experiment at the Pantheon, in Paris. Unless we deny the evidence, this experiment proves indubitably the movement of the Earth. It consists in fixing a steel wire by its upper end into a metallic plate, solidly fitted into a ceiling. The wire is then stretched at its lower end by a rather heavy copper ball. A pointer is attached below the ball, and fine sand spread on the ground to receive the trace of this point. We have a long pendulum; and when the pendulum is in motion, it happens that the point does not always trace the same line in the sand. Successive traces which cross at the centre follow each other, and show a deviation in the plane of the oscillations from east to west. In reality, the plane of the oscillations remains fixed; the Earth turns underneath from west to east. This last experiment has placed the seal on the positive proofs of the movement of the Earth.

Thus, like all the heavenly bodies, the Earth revolves. Absolute repose does not exist in the universe; all is in motion; and it is on this universal law of movement that the stability of the world resists.

But a question presents itself here: the Earth turns; We grant it! But is it possible for it to stop? Or what would happen if, by any chance, it ceased, suddenly or by degrees, to revolve in its rapid motion? Let us see; the subject is worth the inquiry, as it is very curious. In trying to reply to this strange question, I wish to give it more importance than it really possesses. That our globe will one day cease to revolve is what we may fearlessly declare impossible; and that with all the authority which belongs to the principles of celestial mechanics. On the part of our world, we have nothing to expect or to fear from this chimera. I say, to fear!

For here are the inevitable consequences which would follow from the simple arresting of the Earth in its course.

Let us first call to mind that the motion of a body situated on the surface of the Earth is composed of two portions—the movement of diurnal rotation of the globe on its axis, and its movement of translation round the Sun. In virtue of the first, the bodies placed on the terrestrial equator travel 1000 miles an hour. This velocity diminishes from the equator, where it is a maximum, to the poles, where it is *nil,* as bodies have naturally so much longer a path to travel as their latitude is less. In consequence of the second movement of the Earth—its revolution in space round the Sun—each particle of its mass travels 68,000 miles an hour.

An idea may be formed of this velocity if we reflect that an express train at full speed does not go more than sixty miles an hour, and that a 24-pounder ball has only, on its leaving the cannon, a velocity of some 300 yards a second.

As every part belonging to a material system in movement is animated with the same motion, if by an abrupt stoppage this system is suddenly brought to repose, the portions which can be displaced at its surface will continue, in virtue of the acquired velocity, to move in their original direction. It is on account of this principle that when your horse suddenly falls under the pole of your rapid chariot, you find yourself unfortunately thrown over the head of your Pegasus. It is also in virtue of the same principle that you must take certain precautions in descending from an omnibus in motion, since your feet being suddenly placed on the immovable ground, whilst your body is still animated with the acquired velocity, you are inclined to tumble forwards.

The Earth is, as we have seen, a more rapid conveyance than omnibuses, carriages, or trains. If it were to stop suddenly, all precautions would, without doubt, be unavailing to avoid instantaneous death. All objects which are not implanted and fixed in the ground, all which only adhere to the surface by the law of gravity, would be immediately, and all together, projected into space with a tremendous velocity—with the velocity, in fact, of the Earth in its orbit. Peaceful pedestrians, labourers, and quiet people, domestic and wild animals, the birds of the air, our carriages and machinery,—all would be sent forth at a single bound in the direction of the movement of the Earth. As to the ocean, which covers two-thirds of the globe, its liquid mass, rushing over the shores, would submerge in the twinkling of an eye the islands and continents in its impetuous course, crowning the edifice of death. Soon it would reach above the highest mountains, and would cause our globe to undergo a transformation of surface, such as the ancient revolutions which have disturbed it have never equalled. Theorists who occupy themselves in finding a natural cause for the Biblical deluge, have not omitted to bring forward this powerful one, and to suggest that the shock of a comet would easily effect this arrest and its sad consequences. We now know that a comet could pass over the Earth without our perceiving it.

Another very curious fact which would follow the annihilation of the velocity of the Earth is this : the centripetal force which attracts the planets towards the Sun being no longer counterbalanced by the centrifugal force, the Earth would fall in a straight line into the Sun. If there were any other beings on the globe besides the fishes to see it, the Sun would be seen to increase visibly, and to swell out gigantically. The Earth would reach it sixty-four days after the shock, and would disappear in its surface as an aerolite does on the surface of the Earth.

Of course our globe is not an exception to the general rule ; the same end would happen to the other planets if they found themselves in the same case. Thus, if the motion of Mercury, Venus, Jupiter, or Saturn, were stopped, these planets would fall into the Sun—the first in fifteen, the second in forty, the third in seven hundred and sixty-seven, the last in nineteen hundred days.

But here is another consequence, still more curious, which would immediately follow from the sudden stopping of the Earth in its course.

It is acknowledged that motion can no more be annihilated than any atom of matter; it may be communicated, divided, or hidden in a certain quantity of other forces, but not annihilated. It may— and this is the important point here— it may be transformed into heat; and it is actually so transformed every time it appears to be lost as motive power. Thus you strike a nail, firmly driven in and immovable, several times: the movement of the hammer not being communicated to the nail, is transformed into heat—you can easily perceive it by the touch. It is needless to multiply examples: every one has proved by experiment this mechanical transformation of heat.

Now, if by any cause the motion which animates our globe should be instantaneously suspended, this motion would undergo this transformation of which we have spoken. The Earth would be all at once heated; and do we wish to know to what degree? The quantity of heat engendered by the arrest of the terrestrial globe due to a colossal shock, would not only suffice to melt the whole Earth, but also to convert the greater part of it to a state of vapour.

This consequence crowns and absorbs all the preceding ones. The Earth would no longer be a planet, its volume and density would be changed entirely, and what we have just pointed out as to the inordinate movement of the bodies on its surface, the overflowing of the seas, and its fall into the Sun, would no longer be applicable; all these consequences suggested by mechanics would be modified according to the force which impeded the movement of the Earth. If this stoppage were only a progressive slackening, the accomplishment of which would require a length of time instead of being instantaneous, the Earth would still become hot enough to cause all living beings on its surface to perish suddenly.

Let us conclude these reflections as we began them, by stating that the question is more curious than important; and that it is very certain we may rest in peace without allowing the slightest trace of imaginary fears, which might at first sight spring up in our minds, to trouble us.

## III.

## THE MOON.

'Le soir ramène le silence,
Assis sur ces rochers déserts,
Je suis dans le vague des airs
Le char de la nuit qui s'avance.

Tout-à-coup, détaché les cieux,
Un rayon de l'astre nocturne
Glissant sur mon front taciturne,
Vient mollement toucher mes yeux.

Doux reflet d'un globe de flamme,
Charmant rayon, que me veux-tu ?
Viens-tu dans mon sein abattu
Porter la lumière à mon âme ?

Descends-tu pour me révéler
Des mondes le divin mystère ?
Les secrets cachés dans la sphère
Où le jour va te rappeler ?

Une secrète intelligence,
T'adresse-t-elle aux malheureux ?
Viens-tu la nuit briller sur eux
Comme un rayon de l'espérance ?

Viens-tu dévoiler l'avenir
Au cœur fatigué qui t'implore ?
Rayon divin, es-tu l'aurore
Du jour qui ne doit pas finir ?'

LAMARTINE.

THE orb of reverie and mystery, the torch destined for the lighting-up of our terrestrial nights, has always been privileged to attract our sight and occupy our thoughts. Reigning over the empire of silence and peace, it seems more mysterious and solitary than any other ; its white and frosted light also adds to the first impressions ; and it remains in the mind as representing night itself. In olden times, the ancients named the sovereign of the silent nights Diana with the silver crescent, or Phœbus with the fair hair.

Attached by indissoluble ties by means of attraction to the Earth from which it is descended, the Moon gravitates round us like a faithful satellite. At the time of its greatest brightness, when it is at its phase of full Moon on rising, it introduces the time of the appearance of the stars, and perceptibly following their course from east to west, it appears their heavenly guide.

Nevertheless, as it makes the circuit of our globe from west to east in about twenty-seven days, it is soon remarked that each day it falls behind the stars which it seems to conduct, and that it possesses a movement independent to that of the celestial sphere. Indeed, it is the nearest heavenly body to us, and it belongs to us as a satellite.

Of all bodies, this is the one we understood the first and best. Since the invention of the first telescopes—scarcely 250 years ago—these primitive instruments whose power was far from attaining the stellar regions, and could only be effectually applied to this nearest body; astronomers, astrologers, alchemists, and all those who were occupied with science, felt themselves urged by a desire to penetrate into the mysteries of this celestial land. The first observations of Galileo did not make less noise than the discovery of America; many saw in them another discovery of a new world much more interesting than America, as it was beyond the Earth. It is one of the most curious episodes in history, that of the prodigious excitement which was caused by the unveiling of the world of the Moon. '*Ce n'est que le premier pas qui coute,*' says the old proverb; at the time of which I speak, only the first step in optics had been taken. scarcely was it made, but a second was claimed with avidity, then the third, and as science did not advance as quickly as was desired, as many years passed without the kingdoms of the Moon and the cities of its inhabitants being discovered, exalted imagination without waiting longer took flight to the new celestial world. Very curious voyages to the Moon then appeared, astonishing excursions, unpardonable fancies, and serious studies were soon eclipsed by the visions of impatient minds. Notwithstanding all this, astronomical discovery rapidly advanced. Encouraged by the first revelations of the telescope, astronomers undertook the complete study of the lunar surface. The aspect of the Moon to the naked eye, that rude face that was seen with little goodwill on its pale disk, was transformed in the field of the telescope, and at first very bright portions and very dark portions were alone distinguished. Examining it more attentively, and increasing the magnifying power of the instrument, it was discovered that the aspect of the details changed according as the Sun was on one side or the other of the Moon; that on the days when the Sun was at the left of the bright portion dark lines were seen to the right, whilst in the opposite case, the dark shadow appeared to the left. It was then easy to prove that the bright portions were mountains, that the dark portions which were close to them were valleys, or low countries; and lastly, that the large plains were lands which reflected the solar light less perfectly.

It was already known that the phases of the Moon were produced by the illumination of the Sun, because when we see entirely the lighted-up portion of the Moon, at the time of full Moon, it is when we are between the Sun and the Moon, and that the side that the Sun entirely lights up is turned towards us; that at the time of the new Moon, the Sun is behind the Moon, and lights up the side that we do not see, and that at the two quarters, we make a right angle with the Moon and Sun, and can see only one half of the portion which the Sun lights up. Observations made with the telescope confirm this explanation by showing that the path of the shadows on the surface is opposed to the direction of the Sun. Later, indeed only a few years ago, this was again confirmed by spectrum analysis, of which I have before spoken, for, on analysing the rays sent us by the Moon, astronomers found indication of identically the same elements as in the light emitted directly by the Sun.

We have then before our eyes a globe, opaque like the Earth, lighted like it by the Sun, and its surface marked with mountains and valleys. This was more than was necessary to incite curiosity. Astronomers then employed themselves specially with our neighbour, and planned a geographical, or more properly, selenographical, map of it, since, as the reader may know, Γή means the Earth, whilst Σέληνη means the Moon.

As astrological ideas on the physical and metaphysical, moral or immoral influences of the Moon were still in full vigour, and man could not, but with the greatest difficulty, free himself from error, even when he wished, which is unfortunately but seldom the case—

> 'L'homme est de glace aux vérités,
> Il est de feu pour le mensonge,'

astrologers continued to interpret the language of the Moon according to the rules of the horoscope, and astronomers gave a description which agreed with the reigning opinions. To the large spots they gave the name of seas, to the small ones lakes or marshes; then they christened the seas, lakes, marshes, mountains, valleys, gulfs, peninsulas, &c., with names connected with the remembrance of virtues more or less legitimately attributed to the orb of night. Thus there were, and are still at the present time on the Moon, the Sea of Plenty, Lake of Dreams, Sea of Serenity, Marsh of Fogs, Ocean of Tempests, Lake of Death, Sea of Humours, Marshes of Putrefaction, Peninsula of Reveries, Sea of Tranquillity, &c., &c., and other names which are not all, as you see by the preceding, in exquisite taste or of graceful sentiment. When it was necessary to name the mountains, the first idea was to name them after the astronomers whose works had been most useful in the advancement of our knowledge of the Moon, and had most brilliantly illustrated this ornament of space. But a consideration of prudence deterred Hevelius, the author of the *Selenographia,* and one which it will not take long to guess—he feared to excite sentiments of jealousy. An astronomer who did not possess a plot of land here was honoured to receive a small heritage in the lunar world; but another, a rich proprietor, was (as it always happens with people of this kind) very angry not to increase his wealth by some part of the Moon. Then the names of the mountains of the Earth were given. There were the Alps, Apennines, Carpathians, &c.; but the vocabulary of our mountains was not sufficient, so they returned to the learned men, but to those who were dead. Aristotle, Plato, Hipparchus, Ptolemy, Copernicus, each had their property in the Moon. Certain travellers, like the author of the *Voyage au monde de Descartes,* have found, on visiting these different lunar countries, that the great men whose names they had arbitrarily received, took possession of them in the course of the sixteenth century, and there fixed their residence. These immortal souls, it seems, continued their works and systems inaugurated on Earth. Thus it is, that on Mount Aristotle a real Greek city has risen, peopled with Peripatetic philosophers, and guarded by sentinels armed with propositions, antitheses, and sophisms, the master himself living in the centre of the town in a magnificent palace. Thus also in Plato's circle live souls continually occupied in the study of the prototype of ideas. Two years ago a fresh division of lunar property was made, some astronomers being generously enriched.

Without taking up our time at present with the inhabitants of the Moon, the souls of those whose illustrious names have served to point out the kingdoms of the Earth, we can continue our narrative by saying, that the satisfactory knowledge which people rapidly acquired of our satellite was due to its great proximity to the Earth, and to the facility with which we see all that passes on its surface. It is indeed so near to us, that after the celestial distances to which we must have familiarised ourselves in the preceding chapters, the distance which separates it from us is but trifling. Even to those whose minds have not visited the ultra-terrestrial regions, the path from here to the Moon is not very long. Navigators of long service who have made four or five voyages round the globe have travelled an equal distance, for in going round the world, the irregularities of the route double the geometric circumference. A body allowed to fall from the lunar orbit would arrive here in 3 days, 1 hour, 45 minutes, and 13 seconds. To go from here to the Moon, it would take rather more time; but if we availed ourselves of steam, one could arrive there in less than a year. At its minimum distance, it is only twenty-eight times and a half the diameter of the Earth, or about 225,719 miles. This is really an insignificant distance.

It is doubtless this proximity which has caused the great reputation of the lunar orb amongst us. No celestial body, except the Sun, has ever had a similar influence. The whole world was accessible to the lunar influences, men, animals, plants, minerals. I have before stated that the astrological opinions with regard to this body were most singular. I must quote some to you; they are really too curious to be passed over in silence. Let us choose one or two good astrologers, learned on the Moon, and let us question them. First regarding the general action of the satellite on the Earth.

Cornelius Agrippa, a famous geomancer, thus expresses himself: 'The Moon is called Phœbe, Diana, Lucinus, Proserpine, Hecate, who govern the months, half-formed; who illuminates the nights, wandering, in silence, with two horns; queen of divinities, queen of heaven, queen of *manes*, who rules over all the elements, to whom respond the stars, to whom return the seasons, and whom the elements obey: at whose direction the thunders sound, the seeds germinate, the germs increase; the primordial mother of fruits, heart of Phœbus, shining and brilliant, carrying light from one planet to another, illuminating by her light all the divinities, stopping various intercourses with the stars, distributing the light rendered uncertain on account of meetings with the Sun; queen of beauty, mistress of shores and winds, giver of riches, nurse of men, governor of all States good and unhappy; protecting men by sea and land. moderating the reverses of fortune; dispensing with destiny, nourishing all which comes out of the Earth, arresting the insults of phantoms, holding the cloisters of the Earth closed, the heights of Heaven luminous, the currents of the sea salutary, and ruling at will the deplorable silence of the lower regions, governing the world, treading Tartarus under foot; of whom the majesty causes the birds which fly in the sky, savage beasts in the mountains, the serpents hidden under the Earth, and the fish in the sea, to tremble.'

According to La Martinière: 'This lunar planet is damp of itself: but, by the radiation of the Sun, is of various temperaments, as follows: in its first quadrant it is warm and damp, at which time it is good to let the blood of sanguine persons; in its second it is warm and dry, at which time it is good to bleed the choleric; in its third quadrant it is cold and moist, and phlegmatic people may be bled; and in its fourth it is cold and dry, at which time it is well to bleed the melancholic. It is a thing quite necessary to those who meddle with medicine to understand the movement of this planet, in order to discern the causes of sickness. And as the Moon is often in conjunction with Saturn, many attribute to it apoplexy, paralysis, epilepsy, jaundice, hydropsy, lethargy, catapory, catalepsy, colds, convulsions, trembling of the limbs, &c., &c. I have noticed that this planet has such enormous power over living creatures, that children born at the first quarter of the declining Moon are more subject to illness, so that children born when there is no Moon, if they live, are weak, delicate, and sickly, or are of little mind or idiots. Those who are born under the house of the Moon, which is Cancer, are of a phlegmatic disposition.'

According to Eteilla, the Moon 'governs comedians, butchers, tallow and wax chandlers, ropemakers, lemonade-vendors, publicans, play-wrights of all kinds, masters of great works, menageries of animals; and, on the other hand, professional gamblers, spies, sharpers, cheats, bankrupts, false money-coiners, and mad-houses; that is to say, the Moon rules over all those whose business it is to work during the night until sun-rising, or to sell provisions for the night; and it also rules over all which people would be ashamed to commit in full day, in sight of those who have manners. Thus each reader, on reading, may easily find out of what denomination he is, &c. It is well to mention, that the Moon also governs all small merchants, who merely distribute imports, all usurers, courtiers, horse-dealers, place-hunters, men without employment, feeding on clients, and placing by their craft honest people in peril of losing . . . 'It is not without a cause, one would say, with regard to these accusations that the Moon is so near us; if it were as far off as Saturn, it would not be able to answer to all of them.'

But intelligent and animated beings alone were not subjected to these pernicious influences, all terrestrial nature, including vegetables and minerals, was under its rule.

Cucumbers increase at full Moon, as well as radishes, turnips, leeks, lilies, horse-radish, saffron, &c.; but onions, on the contrary, are much larger and better nourished during the decline and old age of the Moon than at its increase; and during its youth, and fulness, which is the reason the Egyptians abstained from onions, on account of their antipathy to the Moon. Herbs gathered while the Moon increases are of great efficacy. 'If vines are trimmed at night when the Moon is in the sign of the Lion, Sagittarius, the Scorpion, or the Bull, it will save them from field-rats, moles, snails, flies, and other animals. Pliny asserts that *aulx* sown or transplanted, the Moon being below the horizon, and gathered the day that it is new, will have no bad odour, and will not cause the breath of those who partake of them to be either offensive or disagreeable.'

## IV.

## THE MOON—(CONTINUED).

'Hail to thy cold and clouded beam,  
Pale pilgrim of the troubled sky!  
Hail, though the mists that o'er the stream  
Lend to thy brow their sullen dye!  
How should thy pure and peaceful eye  
Untroubled view our scenes below?  
Or how a tearless beam supply!  
To light a world of war and woe?'  
Sir Walter Scott, *Rokeby.*

There is, indeed, a great contrast, not only apparent but real, between the serene tranquillity of the lunar disk and the great movements which are ceaselessly carried on on the surface of our world. On approaching the Moon, nothing is seen of the physical causes which make the Earth a vast laboratory wherein a thousand elements contend or unite with each other. There are none of those tumultuous tempests which sometimes sweep over our inundated plains; none of those hurricanes which descend in waterspouts to be swallowed up in the depth of the sea; no wind blows, no cloud rises to the heavens. There white trains of cloudy vapours are not seen, nor those leaden masses with heavy cohorts; the rain never falls; and neither snow, nor hail, nor any of the meteorological phenomena, are manifested there.

But, on the other hand, the magnificent tints which colour our sky at sunrise and twilight, the radiation of the heated atmosphere, are never seen there; if winds and tempests never blow, neither is there the balmy breeze which descends upon our coasts. In this kingdom of sovereign immobility, the lightest zephyr never comes to caress the hill-tops; the sky remains eternally asleep in a calm incomparably more complete than that of our hottest days when not a leaf moves in the air. This is because on the surface of this strange world there is no atmosphere. From this privation results a state of things difficult to realise. In the first place, the absence of air implies also the absence of water and every liquid, for water and liquids can only exist under atmospheric pressure: if this pressure is taken away they evaporate and their beds are dried up. Thus, for instance, if you place a vessel filled with water under the receiver of an air-pump, and then, by pumping out the air which is in the receiver, you make a vacuum, you will soon see the water boil, even when the place where the experiment takes place is frozen with the most intense cold. The boiling disengages vapours, and, finally, the water is evaporated. Now let us suppose, that, at a certain period of its past existence the Moon had, like the Earth, seas and rivers, and that by the aid of any apparatus, its seas and rivers were made to boil and to fall into vapour again; by continuing this operation long enough the Moon would be made completely dry: this is precisely what has happened. Since the distant period of its formation in a fluid state, it has lost all its liquids and vapours, and now a linnet would die of thirst in the midst of the seas of the Moon. These seas do not contain a drop of water. These, it will be said, are singular seas. And, indeed, no one will hold that their title is logical. But, we have seen that they were named at a time when people did not know the lunar surface sufficiently well to guess that it existed without air and water. From the absence of air follows another very curious fact—the absence of sky. On the surface of the Moon when the looks are directed towards the sky, there is none to be seen. An immensity without depth is traversed by the sight without resting on any kind of form, and in the day as in the night are seen the stars, planets, comets, and all the bodies of our universe. The Sun passes among them without extinguishing them, as it does to us. Not only does the Moon not possess this perpetual diversity which the movements of the air produce on our world, but it has not the azure vault which covers the Earth with such a magnificent dome; space is a black and a perpetually black abyss.

Whilst on high there reigns darkness, below there is silence. Not the least sound is ever heard; the sigh of the wind in the woods, the rustling of foliage, the song of the morning lark, or the sweet warbling of the nightingale never awakens the eternally dumb echoes of this world. No voice, no speech has ever disturbed the intense solitude with which it is overspread. Unchangeable silence reigns there in sovereignty. Tall perpendicular mountains divide its surface. Here and there are seen worn-out craters rising towards the sky, white rocks heaped up like the ruins of some long-passed revolution, crevasses crossing the surface as in lands dried by the burning rays of long summer days. That which renders the spectacle more strange is that the absence of vapours causes the absence of perspective as well as the absence of all tints, and we see only white or black according as the object is in the Sun's light or in shadow, the objects succeeding each other as far as the horizon without losing brightness or contour. In the vicinity of the Southern pole, that is to say, at the lower part of the Moon as seen with the naked eye, are the highest mountains of the satellite: Doerfel, whose top attains a height of 26,691 feet above the level of the neighbouring plain; Casatus and Curtius, 7600 and 7318 yards; Newton, 23,853 feet in depth; this word depth may justly be questioned when it refers to the elevation of a mountain; but the Moon is such a singular world that its mountains may be measured as well by depth as height. This paradox, rather difficult to understand, arises from the fact that the mountains of the Moon are not like those of the Earth, but are hollow. When we arrive at the top there is a ring, the interior of which often descends below the surrounding plain: so that if one did not wish to make the round of the slopes which sometimes measure 310 miles (Ptolemy), and even 403 miles in circumference (like the circle of Clavius), it would be necessary to descend three or four miles to cross the bottom of the crater, and afterwards to ascend on the opposite side of the ring, to return at last into the plain.

The views of Copernicus and a lunar landscape give an idea of this singular kind of mountain. Among the annular mountains may be mentioned that of Aristillus, situated in the Sea of Rains, not far from the Caucasus, between the Marshes of Fogs and Putrefaction. It is a curious fact that the surface of the lunar hemisphere was known before that of our own Earth, and the heights of all its mountains were measured before the same thing was done for our own. The volcano of Aristillus in particular was one of the first and best known. Lecouturier, the author of a very good map of the Moon, gave a long description of it, and this description may be applied to most of the lunar mountains. It is composed of a crater about twenty-four miles across, from the centre of which rise two cones, the highest of which attains nearly 984 yards; the whole is surrounded by a circular rampart, the highest part being 3608 yards high. When the bottom of the crater is examined with a powerful telescope and under favourable circumstances, numerous rough portions are noticed which seem to indicate hardened lava and blocks of rock heaped together. From this mountain, taken as a centre, start five or six lines and rocky ramifications directed towards the east and south. These ramifications give rise to the radiation of Aristillus. They are surmounted by an enormous quantity of peaks or basaltic columns which rise from their summits, and make them resemble from afar the multitude of bell towers that are seen on some Gothic cathedrals. Aristillus presents the general aspect of most of the mountains of our satellite.

Thus the Moon would appear very inhospitable to us. The sense of speech, like the sense of hearing, would be lost, and, consequently, would not exist. To the privation of these two senses, perhaps, must be added an inferiority in the pleasures which sight gives to us, seeing that wherever the eye would be directed, it would only meet with

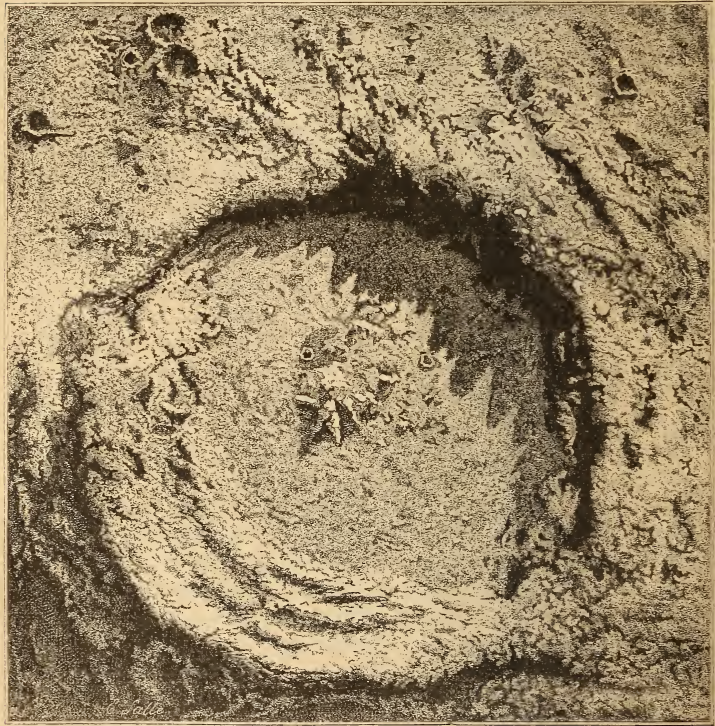

Fig. 46. Copernicus.

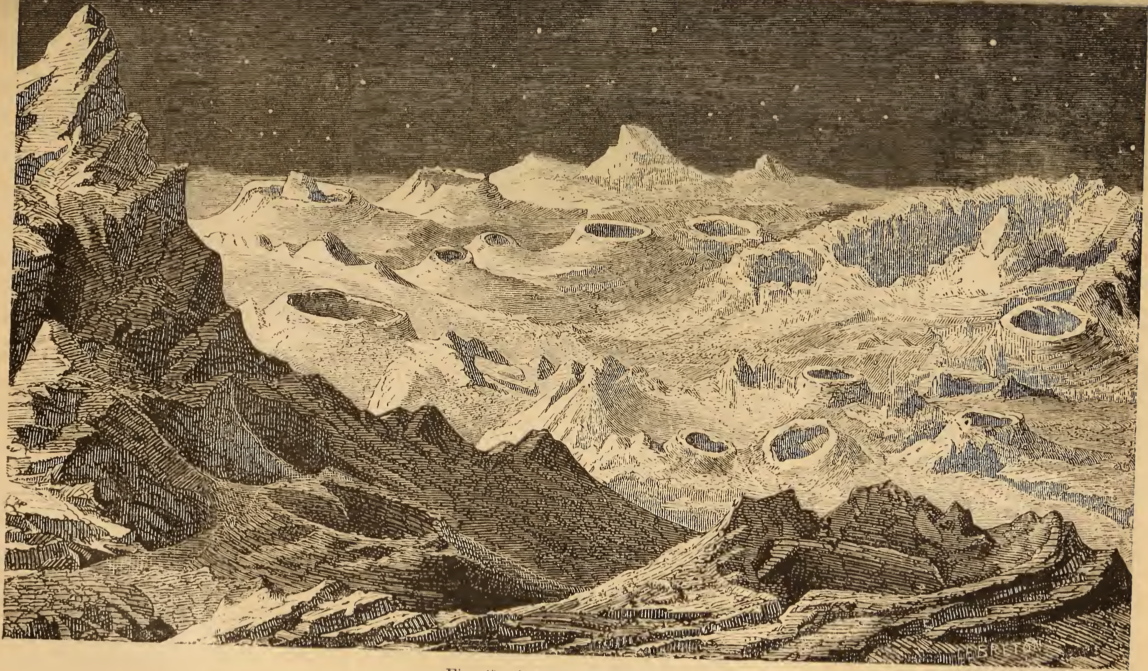

Fig. 47. A Lunar Landscape

white, rugged and sterile mountains, and lofty and deserted craters. These solitary and dried-up landscapes show how true were the lines of Alfred de Musset :—

'Va, Lune moribonde,
Le beau corps de Phœbé
La blonde
Dans là mer est tombé.
Tu n'en es que la face,
Et, déjà tout ridé,
S'efface
Ton front dépossédé.'

This reminds me of what Fontenelle said regarding the changes at work on the surface of our satellite, caused, not by the movements of life, like those which regulate terrestrial nature, but by the simple falling down of lands. 'Everything is in perpetual motion,' he says; 'even including a certain young lady, who was seen in the Moon with a telescope about forty years ago, everything has considerably aged. She had a pretty good face, but her cheeks are now sunken, her nose is lengthened, her forehead and chin are now prominent to such an extent, that all her charms have vanished, and I fear for her days.'

'What are you relating to me now?' interrupted the Marchioness.

'This is no jest,' returned the author. 'Astronomers perceived in the Moon a particular figure which had the aspect of a woman's head, which came forth from between the rocks, and then occurred some changes in this region. Some pieces of mountain fell, and disclosed three points which could only serve to compose a forehead, a nose, and an old woman's chin.' I do not know whether the face, of which the ingenious writer speaks, existed anywhere but in his imagination; but changes, even caused by simple fallings, are extremely rare, if even they are still produced. For a hundred years, for instance, during which period a day has not elapsed in which the Moon has been visible, without it being observed by the telescope, the slightest movement has never been noticed. At the commencement of the century, it is true, people fancied they observed active volcanoes, but they have since discovered that very probably what were then taken for volcanoes were nothing more than the white crests of certain mountains, their form or their structure being more favourably adapted to reflect light. Thus the orb of night remains dumb and silent, revolving in the heavens like a deserted planet. Why this sad and solitary fate? Why deprived of movement and life? This is the question asked by the poet Shelley:—

> 'Art thou pale for weariness,
> Of climbing heaven and gazing on the earth,
> Wandering companionless
> Among the stars that have a different birth,
> And ever changing, like a joyless eye
> That finds no object worth its constancy?'

Now that I have pointed out how the Moon is an inhospitable world, poor and destitute of nature's gifts, it is necessary to retrace my steps, and show it to you as a magnificent world, worthy our admiration and esteem. I do not wish to contradict my foregoing words; but in order not to leave a bad impression with regard to our faithful friend. I wish to remind you that nature, even when it appears to disgrace some of its works from some points of view, favours them with very desirable riches when regarded under other aspects.

To an astronomer, the Moon would be a magnificent observatory. In the daytime, he could observe the stars at noon, and thus discover, without trouble, that they reside eternally in the heavens. With us, on the contrary, among the ancients, were a great number who imagined that they were lighted up in the evening and extinguished in the morning. If, then, people make astronomical observations on the Moon, the Sun is not a tyrant who governs the heavens absolutely, it allows the stars to be enthroned peaceably with it in space; and studies commenced during the night can be carried on without difficulty during the day until the following night. On our satellite the nights are fifteen times 24 hours long, and the days are of the same length; but there is an essential difference to remark between the nights of the lunar hemisphere, which faces us, and those of the hemisphere which we do not see.

You must have noticed that the Moon always presents the same side to us. From the beginning of the world it has never shown but this side. We read in Plutarch, who wrote nearly two thousand years ago, a thousand conjectures relative to the side of the Moon for ever turned towards us. Some said it was a large mirror, well polished and excellent, which sent back from afar the image of the Earth: the dark portions represented the oceans and seas, while the bright portions represented the continents. Others believed that the spots were forests, where some placed the hunts of Diana, and that the most brilliant parts were the plains. Others, again, saw in it a very light, celestial Earth; they stated that its inhabitants must pity the Earth which is below them, and which is only a mass of mud. Others, again, and their singular opinion was widely spread, added that the beings who peopled it were fifteen times larger than those of our Earth, and by the side of the lunar trees our oaks would only be small bushes. All this to explain the nature of the lunar face eternally turned towards us.

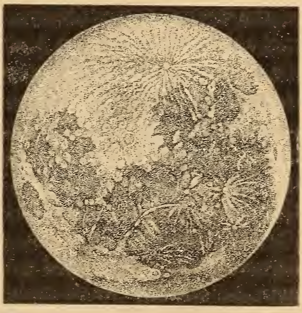
Fig. 48. Aspect of the Full Moon.

Now, if we never see but one side of the Moon, it follows that there is only one side of this body which sees us; so that half of the Moon has a moon—namely, our Earth, and the other half is deprived of one. If there are any inhabitants on the hemisphere turned from us, they do not guess that the Moon is only a body placed for the illumination of our nights, and they must be greatly astonished when the narratives of travellers relate to them the existence of our Earth in the heavens. If the travellers there resemble those here, what tales must they spread with regard to us? But, also, how useful must the Earth be to the lunar nights, and how beautiful we are—from afar! Fancy to yourself fourteen moons like that which gives us light, or more properly speaking, a moon with fourteen times the extent of surface, and you will have an idea of the Earth as seen from the Moon. Sometimes it only presents a fringed crescent, a few days after the new Earth; sometimes it presents the first quarter; sometimes it shines out with its full disk, spreading its silvered light in floods. The most fortunate thing is, that it begins to shine precisely in the evening, that its brightest light, its full disk, is precisely at midnight, and that it fades away in the morning at the time when it is no longer required. And it is known that from the evening to the morning is fifteen times twenty-four hours with our neighbours the Selenites. How much more reasonable are these inhabitants than we are in believing that the Moon was created and placed in the world expressly for them, and that we are only their very humble servants!

In some aspects then the Moon appears much more favoured than the Earth. But not in planetary importance, for it measures scarcely the quarter the diameter of the Earth, 2,153 miles; its total surface is 14,568,000 square miles, including both hemispheres, that is to say, nearly the thirteenth part of the terrestrial surface; its volume is one forty-ninth of the volume of the terrestrial globe. This would probably not prevent its inhabitants (if there are any) from fancying themselves superior to us, and believing us to be their servants rather than their masters; for it is generally known, that the smaller people are, the more vanity they possess. The inhabitants of the invisible hemisphere have the most beautiful nights imaginable, and those who live on the visible hemisphere one of the most beautiful moons. Only the inhabitants of the first moons of Jupiter and Saturn would be able to claim the superiority of their respective planets. Never any clouds, never any tempests, come to disturb these lonely and silent nights; profound calm, unalterable peace, occupy these regions. Moreover, whilst we only know a portion of their world, ours, turning on its axis in twenty-four hours, is entirely unveiled to them, so that with good eyes or with optical instruments they are able to contemplate our Earth revolving over their heads, presenting to them in turn the different countries of our abode. There, the new world stained with cruel battles;* further on, gloomy isles, where they sacrifice human heads to the serpent Vaudoux; here, Russia crushing Poland, who resists strongly; and to the left, a small verdant spot, where thirty-eight millions of French regard in various ways a throne which rises up in the midst of a great city. And ourselves, we contemplate the pensive Moon in the stillness of night, hoping that its people and those of other worlds are more united than our family. Yes, beloved light of the solitary nights, we think that nature has given thee some compensation for the things of which thou art deprived, and that the unknown riches of thy abode would strangely surprise those who for thee would escape from our world. We have seen that thou hast no air, and that thou hast not a drop of water to quench thy thirst; but that does not prevent us from returning to our old sympathy for thy beauty. If thou hast not the elements which suit us, if water and land, air and fire, do not reside in thy midst, thy nature is different, and thou art not less complete in thy creation.

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* This line was written in 1865. The American war is now ended, after having destroyed nearly a million soldiers.

Remain in the heavens of our reveries, renew those phases which form our months, pour out thy dew of light into the limpid air; the traveller will always love to choose thee as his guide in the midnight hours, in the paths of the sea, or in desert countries.

'T'aimera le pilote
Dans son grand bâtiment
    Qui flotte
Sur le clair firmament.

T'aimera le vieux pâtre
Seul, tandis qu'à ton front
    D'albâtre
Ses dogues aboieront.

Et toujours rajeunie,
Tu seras des passants
    Bénie,
Pleine lune ou croissant.'

## V.

## ECLIPSES.

In the circle which it describes round the Earth, the Moon passes every fifteen days between the Sun and us—at the time of new moon—and every fifteen days it is on the opposite side of the Sun (the Earth being between it and the Sun); this is at the time of full moon. Now it happens, sometimes, that it passes exactly between us and the Sun, instead of passing a little above or below it, as it does in most cases. When this occurs, the light of the radiant body naturally finds itself stopped, in part or altogether, according as the lunar disk hides from us a part or the whole of the solar disk. There is, then, an eclipse of the Sun, either partial or total.

On the other hand, it happens sometimes that the Moon, passing behind the Earth, arrives just in the shadow which the Earth throws behind it,—as every illuminated object does. When it is in this shadow it no longer receives the light of the Sun, and, as it only shines by this light, it loses its brightness. Its whole disk completely loses its light if it is wholly within the cone of the Earth's shadow; it remains half illuminated if, passing by the edge of the cone, it only half enters it. In these circumstances there is an eclipse of the Moon, either total or partial. Nothing, therefore, is so simple as an eclipse. When you have a lamp with a radiant globe before you, if you pass your hand before your eyes, you momentarily intercept the light which illumines you; to you it is an eclipse of the lamp by your hand. The same thing is produced when there happens on the Earth an eclipse of the Sun by the Moon. If, now, you turn round, leaving the lamp behind you, and again pass your illuminated hand before your face, it will be momentarily in the shadow of your body. This gives an idea of what happens in an eclipse of the Moon, when it passes into the shadow of the Earth.

If the movements of the Moon were performed exactly in a plane, the prolongation of which passed through the Sun and Earth, there would be an eclipse of the Sun every new moon, and an eclipse of the Moon every full moon. But the orbit in which the Moon moves is inclined a little to this plane, and oscillates from one side to the other, so that eclipses are very variable in their number and magnitude. Nevertheless, this variety has its limits. There cannot be less than two eclipses a year, and not more than seven. When there are only two, they are both eclipses of the Moon. These phenomena return nearly in the same order at the end of eighteen years and ten days; a period known to the Greeks under the name of the Metonic Cycle, and which the Chinese themselves used more than three thousand years ago, to predict their eclipses.

However simple the cause of this phenomenon may be, now that it is known—and known causes are always so simple, that one asks why they were never known before—however easy this explanation appears, for a long time the human race was astonished at the passing absence of the Sun's light during the day; for a long time it felt full of fear and disquietude before this unexplained wonder. The light of day was rapidly diminished, and suddenly disappeared without the sky being darkened by any cloud. Darkness instead of light, stars shining in the sky, nature seeming surprised and astonished; the combination of these unusual events is more than sufficient to explain the momentary terror with which individuals, and, indeed, whole nations, allowed themselves to be carried away in these solemn moments. By reason of the Moon's rapid motion, a total eclipse never lasts longer than five minutes; but this short period is sufficient to allow a thousand sentiments to succeed each other in the terrified mind. The disappearance of the light of the Moon, sometimes caused great trouble to ignorant minds; with how much more reason would the disappearance of the orb of day cause inquietude and fear!

'History is full of the examples of fear caused by eclipses,' says Francœur, 'and dangers caused through ignorance and superstition.' Nicias had resolved to leave Sicily with his army; but, frightened by an eclipse of the Moon, and wishing to delay several days, to assure himself if our satellite had lost nothing after this event, he missed the opportunity of retreat: his army was destroyed, he himself perished, and this misfortune commenced the ruin of Athens.

Often it has been seen that clever men have taken advantage of people's terror during eclipses, either of the Sun or the Moon, to gain their wishes. Christopher Columbus, reduced to sustaining his soldiers on the voluntary gifts of a savage and poor nation, and nearly losing this resource and perishing with hunger, gave out that he was about to deprive the world of the Moon's light. The eclipse began, terror seized the Indians, and they returned, bringing to the feet of Columbus the accustomed tribute.

Drusus appeased a sedition in his army by predicting an eclipse of the Moon; and, according to Livy, Sulpitius Gallus, in the war of Paulus Emilius against Perseus, used the same stratagem. Pericles, Agathocles, king of Syracuse, and Dionysius, king of Sicily, nearly fell victims to the ignorance of their soldiers. Alexander, near Arbella, was obliged to use all his skill to calm the terror that an eclipse had cast over his troops. Thus it is that superior men, rather than sink under the circumstances which oppress them, exert their art to turn them to their profit.

How many fables were built on the idea that eclipses were the effect of Divine wrath, which avenged the iniquities of man by depriving him of light! Sometimes Diana sought

Endymion in the mountains of Caria; sometimes the magicians of Thessaly caused the Moon to fall on the herbs destined for enchantment.

Now it is a dragon which devours the Sun, and whole nations seek to frighten it away by cries; or it is supposed that God holds the Sun enclosed in a tube, and hides or shows us the light by means of a shutter, &c. The progress of science has proved the absurdity of these opinions and fears, since it is known to be possible to calculate by astronomical tables, and to predict a long time beforehand, the instant when the wrath of heaven will burst forth. Nevertheless, not long ago, this terror caused misfortunes in the army of Louis XIV. near Barcelona, at the time of the total eclipse of 1706; and the device of this monarch, *Nec pluribus impar*, has given rise to injurious allusions.

Biot gives us, in his *Etudes sur l'Astronomie Indienne et Chinoise*, very curious details on the rites which presided and which still preside over the observation of the eclipses in the Celestial Empire. The Emperor is considered to be the son of heaven; and with this title his government ought to present the picture of the immutable order which governs the celestial movements. When the two great luminaries—the Sun and the Moon—instead of following their own routes separately, cross each other's paths, the regularity of the order of the heavens appears to be upset; and the disturbance which is there manifested must have its likeness, as well as the cause, in the disorders of the government of the Emperor. An eclipse of the Sun was then considered as a warning given by heaven to the Emperor to examine his faults and correct them. When this phenomenon was announced beforehand by the appointed astronomer, the Emperor and grandees of his court prepared themselves by fasting, and dressing themselves in garments of the greatest simplicity. On the appointed day the mandarins attended at the palace with bows and arrows. When the eclipse commenced, the Emperor himself beat on the drum of thunder the '*roulement* *du prodige,*' to give the alarm; and at the same time the mandarins let fly their arrows towards the sky to aid the eclipsed body. Gaubil quotes these particulars from the ancient Book of Rites, and the principals are announced in the Tcheou-li. After this, the discontent that would be caused by an eclipse not taking place at the time predicted may be imagined; and likewise if one suddenly appeared without being predicted. In the first case, the whole ceremonial was found to have been uselessly prepared; and the desperate efforts which, in consequence of the want of preparation, were made in the second case, inevitably produced a disorderly scene compromising to the imperial majesty. Such errors, although so easily made, placed the poor astronomers in danger of losing their goods, their office, their honour, and sometimes their life. Such a disgrace happened in the year 721 of our era: the Emperor Hiouen-Tsong sent for a bonze Chinese, called Y-Hang, renowned for his knowledge of astronomy. After having shown himself very learned, he had the misfortune to predict two eclipses of the Sun, which were ordered to be observed throughout the whole Empire. But no one saw anywhere on the appointed days any trace of an eclipse, although the sky was almost everywhere serene. To clear himself he published a work, in which he pretended that his calculation was exact, but that heaven had changed its rules of movement—doubtless in consideration of the high virtues of the Emperor. Thanks to his reputation, otherwise deserved—perhaps, also, to his flattery—he was pardoned.

The same ideas on the importance and signification of the Moon and Sun which existed with the Chinese more than four thousand years ago, remain at the present day, and are still powerful, causing the same demands; but they have become less perilous for astronomers, as these phenomena are now predicted several years in advance, with a mathematical certainty, in the great ephemerides of Europe and America, which can easily be procured. M. Stanislas

Julien found in the *Recueil des Lois de Chine* the complete description of the ceremonies still prescribed and practised at the present day on this occasion. The following is a specimen :—

> 'Every time that an eclipse of the sun occurs, pieces of silk are attached to the door of the minister of the rites, called I-men ; and in the great hall they place a table to burn the perfumes at the top of the tower called Lou-thaï (tower of the Dew). The imperial guard places twenty-four drums on both sides, inside the door I-men ; the Kiaofan-ste places musicians at the base of the tower Lou-thaï ; he places also each magistrate in a part of the tower, at the spot where they must bow down to salute. All are turned towards the sun. When the president of astronomy has announced that the eclipse has begun, all the magistrates, in court garments, arrange themselves and stand up. At a given signal they fall on their knees, and then the music begins.
>
> 'Each magistrate makes three prostrations and nine bows, after which the music stops. When the magistrates of the tribunal of the rites have finished offering the perfumes, all the others kneel down. The Kiaosse-Koran advances with a drum, which he strikes to release the sun. The president of the ministry of rites gives three beats of his drum, and then they all strike theirs together. When the president of the astronomical office has announced that the sun has recovered its circular form, the drums stop. Each magistrate kneels three times, and touches his head nine times on the earth. The music recommences ; when these ceremonies are over, the music stops ; then all the magistrates return each to his own side.
>
> 'When the moon is eclipsed they assemble in the office of the Taï-tch'ang (president of the ceremonies), and they observe the same rites for the deliverance of the moon as for the sun.'

In civilised countries, people no longer fear the arrival of eclipses, or think that eternal night is spreading over the

Earth. It is known that these are celestial phenomena studied and understood like many others, resulting from known movements and determined beforehand. They have entirely lost their supernatural character, and belong to a purely physical order of things. At the present time astronomers predict the eclipses of the Sun and Moon, in the same manner as they have discovered past eclipses, by calculation, and have thus been able to assign more exactly certain dates in history. They know at what time the Moon will pass before the Sun, and will rob us of a portion, more or less great, of its light; and the proof is, that I can even now (in 1865) give you the times at which all the eclipses which will happen to the end of this century will occur. I will not give the list, and cover these pages with dates, but to convince you I will point out the total eclipses of the Sun, which will be visible at the places indicated until the year 1900. They are not numerous, as you see.

December 22, 1870, a total eclipse of the Sun at the Azores islands, in the south of Spain and Italy, in Algeria and Turkey; August 19, 1889, a total eclipse of the Sun at the north-east of Spain, southern Russia, and central Asia; August 9, 1896, a total eclipse of the Sun in Siberia, Lapland, and Greenland; lastly, May 28, 1900, a total eclipse in the United States, Spain, Algeria, and Egypt.

I do not doubt but you will be a witness with me at the last one, and will thus be in a position to prove the truth of this prediction. Unfortunately, not one of them will be visible at London; but if our inventions with steam and electricity continue, and others come to their aid, the Earth will soon be but one country, and we shall travel from here to Pekin, as we did last century from Paris to St. Cloud.

In stating that the eclipses of the Sun and Moon are no longer a terror to us, I do not mean that they no longer make any impression. No; the sudden impressions caused by the spectacle of the rarest phenomena of nature are independent of our reflection, and the sudden absence of the solar light in the middle of the day, produces in all beings an emotion from which they cannot free themselves. The narrative of the effect produced by eclipses on man, and even on animals, is too interesting not to be presented to you in concluding this chapter. I shall choose as narrator an eye-witness of the total eclipse of July 1842, whose talent is too well known for it to be praised; I refer to Arago, who thus gives us his impressions, enriched with other proofs, to which he attributes such high value as to place them with his own. (See *Popular Astronomy*, Vol. III.)

'Riccioli relates, "that during the total eclipse of 1415 birds were seen in Bohemia to fall down dead with fright." The same is said relative to the eclipse of 1560; some eye-witnesses say: "the birds, strange to say, fell to the ground, seized with fear." In 1706, at Montpellier, the observer said, "bats flitted about as at the beginning of night. Fowls and pigeons ran precipitately to their roosts. The small birds that had been singing in their cages became silent, and put their heads under their wings. The animals employed in the labours of the field all at once halted."

'The alarm occasioned among beasts of burden by the sudden transition from day to night, is registered also in Louville's memoir relative to the eclipse of 1715, thus: "horses that were labouring or employed on the high roads lay down. They refused to advance."

'Fontenelle relates, that in the year 1654, at the mere announcement of a total eclipse, a multitude of the inhabitants of Paris hid themselves in deep cellars.

'Thanks to the progress of science, the total eclipse of 1842 found the public in a very different disposition from that which they manifested during the eclipse of 1654. A lively and legitimate curiosity had taken the place of puerile fears. The poorest villagers of the Alps and Pyrenees repaired in crowds to the places whence the phenomenon could be best seen; they did not doubt, with some rare exceptions, that the eclipse had been correctly announced: they regarded it as a natural, regular, and calculable event, about which good sense taught them not to be uneasy.

'At Perpignan, only persons who were confined to their chambers by ill-health remained at home. Early in the morning, the terraces, the ramparts of the town, the hills outside, whence the sunrise could be best seen, were crowded. In the citadel, beside the numerous groups of citizens seated on the glacis, we had beneath us all the soldiers collected in a vast square to be reviewed. The time for the commencement of the eclipse was approaching. Nearly twenty thousand people, with smoked glasses in their hands, were examining the radiant orb projected on the azure sky. We had scarcely, though provided with powerful telescopes, begun to perceive a slight indentation in the Sun's western limb, when an immense shout, the commingling of twenty thousand different voices, proved that we had only anticipated by a few seconds the naked-eye observation of twenty thousand astronomers equipped for the occasion, and exulting in this their first trial. A curiosity, animated by the desire of not being outdone, seemed to have inspired the natural sight with an unusual degree of penetration and power.

'Between this time and that which just preceded the entire disappearance of the Sun, we did not remark anything in the countenances of the spectators deserving of mention. But when the Sun, being reduced to a narrow filament, began to throw only a faint light on our horizon, a sort of uneasiness took possession of the mind, each person felt an urgent desire to communicate his emotions to those around him. Then followed a hollow moan resembling that of a distant sea after a storm, which increased as the slender crescent diminished. At last the crescent disappeared, darkness instantly followed, and this phase of the eclipse was marked by absolute silence, as distinctly as it was by the pendulum of the astronomical clock. The magnificence of the phenomenon had triumphed over the petulance of youth, over the levity affected by some of the spectators as indicative of mental superiority, over the noisy indifference usually professed by soldiers. A profound calm also reigned throughout the air; the birds had ceased to sing.

'After a solemn expectation for two minutes, transports of joy and frenzied applause spontaneously and unanimously saluted the return of the solar rays. The sadness produced by feelings of an undefinable nature was now succeeded by a lively satisfaction, which no one attempted to moderate or conceal. For the majority of the public the phenomenon had come to a close. The remaining phases of the eclipse had no longer any attentive spectators beyond those devoted to the study of astronomy.

'Even those who appeared to be most deeply moved at the instant of the sudden disappearance of the Sun, amused themselves the very next day, and to my mind unreasonably, with recounting the state of alarm into which many country people had been thrown. Such people, at any rate, made no secret of their feelings. As for myself, I thought it very natural that illiterate persons, who had not been informed by anybody that an eclipse would occur on the morning of the 8th of July, should feel great uneasiness on seeing utter darkness so instantly follow daylight. Let it not be supposed that the idea of a convulsion of nature, the idea that the world was immediately coming to an end, is what would most generally disturb the minds of a rude and simple people. When I questioned them as to the true cause of the despair which had taken possession of them on the 8th of July, they immediately replied: 'The sky was serene, and yet the light of day diminished, and every object grew shadowy, and then all at once we were in the dark. We thought that we had become blind.'

We extract from the *Journal des Basses Alpes*, of July 9, 1842, the following anecdote, which seems to me to be worthy of preservation:—

'A poor child in the commune of Sièges was watching his flock, entirely ignorant of the approaching event; he became uneasy on seeing the sun gradually become dark, for no cloud, no vapour, accounted for the change. When the light suddenly disappeared, the poor child, overcome with fright, took to crying and calling for help! His tears were still falling when the sun again sent forth a ray of light. Reassured by the commencement, the boy crossed his hands, exclaiming in the *patois* of the district, "O beautiful sun!"' (O beou souleou!)

Arago afterwards points out several curious facts on the influence of eclipses on animals:—

'An inhabitant of Perpignan purposely kept his dog without food from the evening of the 7th July. The next morning, at the instant when the total eclipse was going to take place, he threw a piece of bread to the poor animal, which had begun to devour it when the sun's last rays disappeared. Instantly the dog let the bread fall, nor did he take it up again for two minutes, that is, until the total obscuration had ceased, and then he ate it with great avidity.

'Another dog sought refuge between his master's legs, when the sun became eclipsed. In a farm, some fowls, at the instant of total obscuration, suddenly left the millet that had just been given them, and sought refuge in a stable. At the Mas de l'Asparron, the fowls being far from any habitation, went and grouped themselves under a horse's belly. A hen attended by a brood of chickens hastily called them to her, and covered them with her wings. Some ducks which were swimming about in a pool at the instant of the sun's disappearance, did not attempt to regain the farm which they had left two hours before, but huddled together in a corner.

'At La Tour, chief town of the canton, in the Eastern Pyrenees, an inhabitant had three hen linnets. On the 8th of July, very early in the morning, on hanging the cage up in the drawing-room, he remarked that the birds looked very well; after the eclipse one of them was found to be dead. Are we to suppose that the linnet in its fright hit itself violently against the bars of the cage? Some facts observed elsewhere tended to render this supposition probable.'

Even insects did not escape a like impression.

M. Lentherie, professor at Montpellier, also gave some details concerning the effects of the total eclipse upon several species of animals. The bats, thinking night had come, quitted their retreats; an owl came out of St. Peter's tower, and flew across the square of the Peyrou; the swallows disappeared; the fowls went to roost; some oxen who were feeding freely near the church of Maguelonne arranged themselves in a circle with their backs towards each other, and their horns outwards, as if to resist an attack.

Some observers at Cremona say, that an immense number of birds fell to the ground; and M. Zamboni, the author of the *Piles Sèches,* is quoted as having seen a sparrow fall beside him. M. Piola, who was under a tree near Lodi, remarked that the birds ceased to sing during the moments of darkness, but none fell.

In a narrative that Father Zantedeschi addressed to Arago from Venice he said that,

> 'Some birds wishing to escape and not being able to see, knocked up against the chimneys and the walls with such violence as to fall down stupefied on the roofs, in the streets, and into the lagoons. Amongst the birds that met with these accidents may be specified some swallows and a pigeon. Other swallows were seized in the streets, their fright having scarcely left them the power of fluttering.
>
> 'Some bees which had left their hive in great numbers at sunrise, returned to it even before the instant of total darkness; and they waited till the sun had entirely resumed its brightness before they ventured forth again.'

These narratives give a sufficient idea of the effect produced by unusual phenomena on the faculties of men and animals. The necessity of order is so deeply attached to creation, that an appearance of trouble throws us out of our normal security, and fills us with fear.

# BOOK V.

# I.

# THE PLURALITY OF INHABITED WORLDS.

> ‘Yet not to earth's contracted span
> Thy goodness let me bound,
> Or think Thee, Lord, alone of man,
> When thousand worlds are round.’
>
> POPE'S *Universal Prayer.*

THE astronomical truths which have been the subject of our conversation, doubtless prove the high character of the human mind which aspires to them, and which, scrutinising the organised laws of the universe, has been able to determine the causes which regulate the harmony of the cosmos and secure its perpetuity. No doubt, it is good for man, this spiritual atom inhabiting a material atom, to have penetrated the mysteries of creation, and to have been exalted to the knowledge of these sublime heights, the contemplation of which alone overwhelms and annihilates him. But if the universe remains to man only a great material mechanism moved by physical forces, if nature is nothing in his eyes but a gigantic laboratory, where the elements are mingled blindly under the most various and casual forms; in a word, if this admirable and magnificent science of the heavens confines the efforts of the human mind eternally to the geometry of the heavenly bodies, the science would never attain its real end, and it would stop at the moment of reaping the fruit of its immense labours. It would remain supremely incomplete if the universe were never anything to it but an assemblage of inert bodies floating in space under the action of material forces.

The philosopher must go further. He must not confine himself to seeing under a more or less distinct form the great body of nature. But, stretching forth the hand, he must feel, under the material envelope, the life which circulates in great waves. God's empire is not the empire of death; it is the empire of life.

We live on a world which is no exception among the heavenly bodies, and which has not received the least privilege. It is the third of the planets which revolve round the Sun and one of the smallest amongst them; without going beyond our system, other planets are much more important than it; Jupiter, for instance, is 1414 times greater, and Saturn 734 times. Whilst it appears to us the most important of the universe, it is in reality lost in the immensity of the worlds which people the heavens, and the whole creation does not guess at its existence.

Of the planets of our own system there are only four, the inhabitants of which can know that the Earth exists; these are, Mercury, Venus, Mars, and Jupiter; and even to this last one it is most of the time invisible in the solar aureola. Now, whilst the Earth is thus lost amidst worlds more important than itself, the other worlds are in the same conditions of habitability as those that we observe on the Earth. On these planets as on our own, the generous rays of the Sun pour forth heat and light; on them, as here, years, months, and days, succeed each other, drawing with them the seasons which, from time to time, support the conditions of existence; on them as here, a transparent atmosphere envelopes the inhabited surface with a protecting climate, gives rise to meteoric movements and developes those ravishing beauties which celebrate sunrise and sunset. On them as here, vaporous clouds rise from the ocean with the deep waves, and spreading themselves under the heaven, carry dew to the parched-up regions. This great movement of life which circulates over the Earth, is not confined to this little planet: the same causes develope elsewhere the same effects, and on many among these strange worlds, far from noticing the absence of the riches with which the Earth is endowed, an abundance of wealth of which our abode only possesses the first-fruits is observed. By the side of these bodies, the Earth is essentially an inferior world in many respects; from the unsatisfactory conditions of geological stability of which the terrestrial spheroid reminds us, its surface being only a thin pellicle, to the fatal laws which govern life on this Earth where death reigns supreme.

If, on the one hand, the other worlds have conditions of habitability quite as powerful, if not more so, as the terrestrial conditions; on the other hand, the Earth, considered in itself, appears to us like an overflowing cup whence life issues on all sides. It seems that to create is so necessary to the order of nature, that the smallest piece of matter of suitable properties does not exist without serving as an abode of living beings. Whilst the telescope discovered in the heavens fresh fields for creation, the microscope showed us below the range of visibility the field of invisible life, and that, not content with spreading life everywhere where there is matter to receive it, from the primitive period when this globe had scarcely left its fiery cradle, to our days, nature still heaps up existence, to the detriment of existence itself.

Leaves of plants are fields of microscopical flocks of which certain species, although invisible to the naked eye, are real elephants beside other beings, whose extreme diminutiveness has not prevented an admirable system of organisation for the carrying on of their ephemeral life. Animals themselves serve as an abode to races of parasites which, in their turn, are themselves the abode of parasites still smaller. Under another aspect the infinity of life presents a correlative character in its diversity. Its force is so powerful that no element appears capable of struggling advantageously against it, and tending to spread itself in every place, nothing can stop its action. From the high regions of the air, where the winds carry the germs, to the oceanic depths, where they undergo a pressure equal to several hundred atmospheres, and where the most complete night extends its eternal sovereignty; from the burning climate of the equator and the hot sources of volcanic regions to the icy regions and the solid seas of the polar circle, life extends its empire like an immense network, surrounding the whole Earth, amusing itself with all obstacles, and passing over all abysses, so that there is not in the world any district which can pretend to be beyond its absolute sovereignty.

It is by studies founded on this double consideration, the insignificance of the Earth in creation, and the abundance of life on its surface, that we are able to raise ourselves to the first real principles on which the demonstration of the universal habitation of the heavenly bodies must be fixed. For a long time, man could confine himself to the study of phenomena; for a long time, he must still keep to the direct and simple observation of physical appearances, in order that science may acquire the precision which constitutes its value. But now this entrance of truth can be passed, and thought, outstripppping matter, may rise to the idea of intellectual things. In the bosom of these distant worlds, it sees universal life plunging its immense roots; and at their surface, it sees this life spreading itself, and intelligence establishing its throne.

Founded on the astronomical basis, the only possible foundation, researches made in the domain of the physical sciences, from celestial mechanism to biology, and in that of the philosophical sciences from ontology to morals, the old idea of the plurality of worlds has risen to the rank of a doctrine. The evidence of this truth has been revealed to the eyes of all those who are impartially and entirely given up to the study of nature. It does not come within the bounds of this discourse to enter fully on this philosophical aspect of creation; but if I consider it in itself as the logical conclusion of astronomical studies, I owe it to my readers at least to offer them as a modest conclusion of the narratives which they have followed up to this time, the principal results to which we have arrived on this great and beautiful question of the existence of life on the surface of the heavenly bodies.

In the first place, the following is the first consideration established on the astronomical character of the world and its history: 'If the reader follow the philosophical march of modern astronomy, he will discover that from the moment when the movement of the Earth and the volume of the Sun were known, astronomers and philosophers found it strange that a body so magnificent was solely employed to light up and warm a little imperceptible world, arranged in company with many others under a supreme rule. The absurdity of such an opinion was still more striking, when they found that Venus was a planet of the same dimensions as the Earth, with mountains and plains, seasons and years, days and nights, similar to our own; the analogy was extended to the conclusion, that these two worlds, similar in their formation, were also similar in their *rôle* in the universe; if Venus was without population, the Earth ought to be equally so; and conversely, if the Earth was peopled Venus must be so also. But afterwards, when the gigantic worlds of Jupiter and Saturn were observed, surrounded with their splendid retinues, they were compelled to refuse living beings to the preceding little planets, if they did not equally endow these, and moreover give to Jupiter and Saturn men much superior to those of Venus and the Earth. And indeed, is it not evident that the absurdity of the immovability of the Earth has been perpetuated, a thousand times more extravagantly in this ill-conceived final causation, the object of which is to place our globe in the first rank of celestial bodies? Is it not evident that this world has been thrown without any distinction into the planetary cluster, and that it is not better adapted than the others to be the exclusive seat of life and intelligence? How little founded is the sentiment which animates us when we fancy that the universe is created for us, poor beings lost on a world, and that 'if we should disappear from the scene, this vast universe would be marred, like an assemblage of inert bodies, and deprived of light! If on the morrow not one of us was to awake, and if the night which, in each diurnal period enwraps the world, for ever sealed the closed eyelids of all living beings, is it to be believed that henceforth the Sun would no longer pour out its light and heat, and that the powers of nature would cease their eternal movements? No; these distant worlds that we have just reviewed, would continue the cycle of their existence, rocked on the permanent forces of gravitation, and bathed in the luminous aureola that the orb of day produces round its brilliant focus. The Earth that we inhabit is only one of the smallest bodies grouped round this focus, and its degree of habitation has nothing which distinguishes it amidst its companions. For an instant place yourself at a distance in space whence you can embrace the whole solar system, and suppose that the planet in which you saw light is unknown to you. For to give yourself freely to the present study you must no longer consider the Earth as your country, or prefer it to other abodes; and then contemplate without pretension and with an ultra-terrestrial eye the planetary worlds which circulate round the focus of our life! If you suspect the phenomena of existence, if you imagine that certain planets are inhabited, if you are taught that life has chosen certain worlds in which to spread the germs of its productions, do you intend to people this small globe of the Earth, before having established in superior worlds the wonders of living creation? Or if you have the intention of settling yourself on a body whence you can embrace the splendour of the heavens, and on which you can enjoy the benefits of a rich and fertile nature, shall you choose as an abode this mean Earth which is eclipsed by so many resplendent spheres? In reply, reader, and it is the least strong and most rigorous conclusion that we can draw from the preceding considerations, let us agree that 'the Earth has no marked pre-eminence in the solar system to entitle it to be the only inhabited world, and that, astronomically speaking, the other planets are arranged as well as it is as abodes of life.'

A second consideration, founded on the varieties of living beings on the surface of the terrestrial globe, on the infinite power of nature, that no obstacle has ever stopped, and on the eloquent spectacle of the infinity of life itself in the terrestrial world, conducts the argument into a new order of ideas: 'Nature knows the secret of all things, puts into action the most feeble as well as the most powerful forces, renders all its creations answerable, and constitutes beings according to the worlds and ages, without the one or the other being able to place any obstacle in the way of the manifestation of its power. Hence it follows, that the habitability and habitation of the planets are a necessary complement to their existence, and that of all the conditions enumerated, not one can stop the manifestation of life on each of these worlds. But let us add another observation which will complete the preceding; let us think for an instant of our forced ignorance in this little isle of the great archipelago where destiny has bound us, and of the difficulty we experience in searching into the secrets and power of nature. Let us prove that, on the one hand, we do not know all the causes which have been able to influence, and which still influence the manifestation of life, its support and propagation on the surface of the Earth; and that, on the other hand, we are still far from knowing all the principles of existence which propagate in other worlds very dissimilar creations. Scarcely have we penetrated those which regulate the daily functions of life; scarcely have we been able to study the physical properties of the media, the action of light and electricity, the effects of heat and magnetism. There exist others which go on constantly under our eyes, and which have not yet been studied nor even discovered. How vain then would it be to wish to oppose to the possibility of planetary existences the superficial and narrow principles of what we call our sciences? What cause would be able to struggle with advantage against the effective power of nature, and to place obstacles to the existence of beings on all these magnificent globes which revolve round the Sun! What extravagance to regard the little world where we first saw light, as the only temple, or as the model of nature!'

Impressed with the value of the providential design of creation, these considerations become more imperious still. 'That our planet was made to be lived in, is incontestable, not only because the beings which people it are here under our eyes, but again because the connexion which exists between these beings and the regions in which they live brings the inevitable conclusion that the idea of habitation is immediately connected with the idea of habitability. Now this fact is an argument in our favour; for, unless we consider the creative power as illogical, or as inconsistent with its real manner of acting, it must be understood that the habitability of the planets imperiously demands their habitation. To what end have they received years, seasons, months, days; and why does not life come forth on the surface of these worlds which enjoy, like ours, the benefits of nature, and which receive, like ours, the rays of the same sun? Why these snows of Mars, which melt each spring, and descend to water its continents? Why these clouds of Jupiter, which spread shade and freshness over its immense plains? Why this atmosphere of Venus, which bathes its valleys and mountains? O splendid worlds which float afar from us in the heavens! Would it be possible that cold sterility was ever the immutable sovereign of yonder desolate regions? Would it be possible that this magnificence, which seems to be your appanage, was given to solitary and bare worlds, where the lonely rocks eternally regard each other in sullen silence? Fearful spectacle in its immense immutability; and more incomprehensible than if Death had passed over the Earth in fury, and with a single stroke mowed down the living population which enlightens its surface, thus enveloping in one ruin all the children of life, and leaving it to roll in space like a corpse in an eternal tomb !'

Thus it is that, under whatever aspect we regard creation, the doctrine of the plurality of inhabited worlds is formed and presented as the only explanation of the final end—as the justification of the existence of material forms—as the crowning of astronomical truths. The summary conclusions which we have just quoted are established, logically and without difficulty, by observed facts ; and when, having contemplated the universe under its different aspects, the mind is astonished at not having sooner conceived this striking truth, it feels within itself that the demonstration of such evidence is no longer necessary, and that it ought to accept it, even with no other reasons in its favour than the condition of the terrestrial atom compared with the rest of the immense universe. Humbled by this spectacle, one can but proclaim the luminous truth in a transport, disdaining all researches.

'Ah ! if our sight was piercing enough to discover, where we only see brilliant points on the black background of the sky, resplendent suns which revolve in the expanse, and the inhabited worlds which follow them in their path, if it were given to us to embrace in a general *coup d'œil* these myriads of fire-based systems ; and if, advancing with the velocity of light, we could traverse from century to century, this unlimited number of suns and spheres, without ever meeting any limit to this prodigious immensity where God brings forth worlds and beings ; looking behind, but no longer knowing in what part of the infinite to find this grain of dust called the Earth, we should stop fascinated and confounded by such a spectacle, and uniting our voice to the concert of universal nature, we should say from the depths of our soul : Almighty God ! how senseless we were to believe that there was nothing beyond the Earth, and that our abode alone possessed the privilege of reflecting Thy greatness and power !' *

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* Camille Flammarion, *La Pluralité des Mondes Habités*, t. ii. iii. and iv.

## II.

## THE CONTEMPLATION OF THE HEAVENS.

How beautiful and worthy of the human mind is this contemplation of the visible splendours of creation! How much superior are these studies to the common preoccupations which occupy our days and pass away our years! How they elevate the soul towards real greatness! In the artificial world that we have formed for ourselves by our citizen habits, we have become so strange to nature that when we return to it we appear to enter into a new world. We have lost belief in its value, and thus deprive ourselves of the purest joys. By freeing ourselves from stormy life, by returning to peace, we undergo a hitherto unknown impression, as if the sphere of harmony into which we enter had always remained far from the labours of our minds.

Studies of nature possess this precious characteristic, that being applied to truth, they recall us to our origin, to our material cradle. Worldly life is a real exile for the soul. Imperceptibly we get accustomed to content ourselves with appearances, no longer to seek the bottom and the substance of things. Imperceptibly we lose our value and greatness, when rocked on the surface of this unfathomable ocean on which float human barks. The objects which surround us alone attract our attention and we forget the past like the future. But there are hours of solitude when the soul, returning to itself, feels the emptiness of all these appearances, when it discovers how little they can satisfy it, when it anxiously searches and returns with love to real greatness alone capable of giving firm ground for its repose, instead of the fluctuations which have agitated it. Then the soul has home sickness; it demands the truth; it wishes for the beautiful, and bids adieu to transient affections. If it is allowed at these hours of reflection to contemplate the beauties of nature; to admire and understand the wonders of creation; entirely giving itself up to the contemplation which captivates it, abandoning itself to the charm of the splendours studied, it devotes itself unreservedly to the spectacle which absorbs it, forgetful of the false joys of the Earth, and eager after the true and profound ones which Nature, that young mother whose age is unchangeable, pours into the souls of the children who cherish her. The beauties of the heavens will captivate it with their charms, it will demand that such a contemplation shall never cease, that the night shall reveal to it wonder upon wonder, and that it may be permitted not to leave that scene before its admiration is satisfied; as in the sweetest hours of life it will be induced to sing with the poet:—

'O temps, suspends ton vol! et vous, heures propices,
Suspendez votre cours!
Laissez-moi savourer les rapides délices
Des plus beaux de nos jours!

'Mais je demande en vain quelques moments encore,
Le temps m'échappe et fuit;
Je dis à cette nuit: Sois plus lente; et l'aurore
Va dissiper la nuit.'

When we give our minds up to these high and magnificent studies we soon feel the great harmony, the admirable unity in which all things are bound together; we feel that all creation is one, that we form a constituent part of it, and that an immense life, scarcely guessed at, envelopes us. Then all phenomena take their place in the universal concert.

The golden star which shines in the depths of the heavens and the little grain of crystallized sand which reflects the solar ray, unite their light; the majestic sphere which revolves harmoniously in its gigantic orbit and the little bird which sings under the leaves; the immense nebula which arranges its system of suns in the vast expanse, and the beehive which receives the rhomboids of a republic in eternal concord; gravitation which bears up in space these formidable globes and these systems of worlds, and the humble zephyr which wafts beloved perfumes from one flower to another; great phenomena and imperceptible actions, unite with each other in the general movement, and the infinitely great and the infinitely small embrace each other. For the universe is the action of a single thought.

No human speech, no work formed by the hand of man, can compete with the harmony of nature or the work of creation. Compare for an instant the most admirable *chef-d'œuvre* among the wonders of art with the most simple among the productions of nature. As was said long ago, compare the richness of regal ornaments, the oriental tissue of Solomon's garments when in all his glory, the golden plates of his temple, the mosaics of his palaces, to the whiteness of the lilies, the bloom of the roses, and seek if the comparison can be thought of for an instant. The great characteristic which distinguishes these works, is that in the one, a restricted power marks the limits of its skill, whilst in the other the impress of an infinite power always remains. Magnify the power of our senses, take that astonishing lens which raises up giants where the most insignificant beings remained invisible; at its focus, the finest tissue, the most delicate work of human art is changed into a shapeless and coarse object; on the other hand, the most modest tissue formed by the hands of nature reveals hidden riches in proportion as the magnifying power increases.

Try now to compare our most wonderful instruments, from our formidable machinery which holds captive those powerful forces of which man has made himself master, to those exact instruments so elegant, so sensitive, with the untamable forces with which matter is animated, or with those admirable and precise laws which rule in an incomprehensible perfection the harmonious movements of the starry spheres at the concert of the heavens, and say how much art is surpassed by nature.

And the work of nature is charming in the infinitely small as in the infinitely great. The sublime spectacles which the contemplation of the heavens unveils to us are doubtless the most striking, the magnificence of which imposes itself most impressively on our astonished mind; but if we examined little things our imagination will remain confounded before them as before the greatest. On the poor little white butterfly which, born yesterday, will be in dust before to-morrow has passed, the analysing eye of the microscope will show magnificent feathers of snowy white or dead yellow, symmetrically arranged, with as much care as those of the eagle intended to fly to the heavens; nevertheless to the naked eye there is nothing but an impalpable dust, which adheres to the fingers. On its head you may count twenty thousand eyes. If the finer drops of dew suspended at sunrise to the leaves of the lower branches, fall at the touch of a passing bird, you will see painted on this fine rain a rainbow not less rich than the gigantic arch uplifted at the end of a storm in the regions of the atmosphere; charming little rainbow, formed for a life of a few tenths of a second and disappearing as it was born. Examine these humble wild flowers with coloured petals; emeralds and rubies succeed each other, gold and sapphire intermingle their delicate tints; it is in miniature the same magnificence of colours as shines in the double stars. We could continue without limit these comparisons which prove to us, in all directions, the infinity of the creative power.

Nevertheless we do not think of it, and we pass indifferently by these wonders. If the night was deprived of stars, said a philosopher, and there was only one place on the Earth whence the constellations and bodies would be visible, the pilgrimage to this place would never cease, and each would wish to admire these wonders. But that which daily surrounds us loses its value, custom destroys attention and we forget nature for pleasures certainly infinitely less worthy of our thoughts. If sometimes we allow ourselves to be exalted by these wonders of the science of the heavens, we quickly return to the things of the world forgetting our grand questions. The Earth has the gift of captivating us so strongly that we willingly forget the heavens for it. How many persons have repeated in prose this ode of Lebrun's to a fellow-astronomer :

'Ami, laisse rouler la Terre
Autour de l'astre des saisons :
Ris et bois : j'aime mieux ce verre
Que l'astrolabe des Newtons.
Qu'importe qu'au centre du monde
Le soleil fixe ses destins,
Pourvu que sa chaleur féconde
Mûrisse toujours nos raisins ?
Tout son plaisir, toute sa gloire,
C'est de colorer ce doux jus ;
Le nôtre, ami, c'est de le boire :
Boire, aimer, que faut-il de plus ?
Crois-moi, sous l'ombre de la treille
Goûte le charme des beaux jours :
Chaque heure en fuyant nous conseille
De ravir des moments si courts.'

Doubtless these are charming thoughts ; but ought one to live for them, and does not the soul sometimes feel the overwhelming desire to rise above the ordinary functions of life ? That all the pleasures and all the glory of the Sun should go to colour the grape is contestable ; but that all our pleasure and glory should be in drinking its juice is a little too material. Let us then assign its part to each thing, let us embellish existence with the flowers of contemplation, and let our aim be to render ourselves more and more heavenly.

Let us consider, dream, and think sometimes of the beautiful in nature. Let us allow ourselves to be drawn away by these delicious reveries which carry us from earthly tumults to calm and silence. Let us ascend to that limpid source, whence descend all consolation in sadness, all coolness after the fatigue of the day, all peace in disquietude. When our lips are parched by the winds of the world, let us moisten them at this clear spring, let us ask a kiss from the lips of Nature,—and may this pure aspiration keep us from poisoned cups.

> 'Heures de poésie, heures trop tôt passées
> Que l'étoile du soir m'apporte avec la nuit,
> Oh ! ne me quittez pas sans porter quelque fruit,
> Sans éveiller en moi quelques nobles pensées.'*

The fulness and height of man's happiness, said Seneca, is to tread under foot all bad desires, to dive into the heavens, and to penetrate the most hidden folds of nature. With what satisfaction, when our thought has taken flight from the midst of these does it mock at the mosaics of our riches, and our earth with all its gold! To disdain these porticoes—these brilliant platforms of ivory—these rivers running through palaces—one must have embraced the circle of the universe, and looked from on high on this narrow globe, a great portion of which is submerged, whilst that which is above water is either savage, or torrid, or frozen. This is, then, says the sage, the spot divided among many nations with fire and sword!

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* Klopstock, by J. J. Ampère.

Here are our mortals, with their absurd frontiers! If the human intelligence were given to ants, would they not also divide a square of garden into several provinces? When thou shalt have risen to the really grand objects of which I speak, each time that thou shalt see armies marching with colours raised, and as if it were a serious matter, horsemen sometimes flying unguardedly, or retreating on their supports, thou wilt be tempted to say, 'These are evolutions of ants—great movements in little space.' Oh! how little is man if he does not rise above human things! There are regions above, without limits, which our soul is admitted to possess, provided that it carries away with it the least possible that is material, and that, being purified from all stain, and free from fetters, it is worthy of flying thither. As soon as it reaches there, it is nourished and developed: it is as if delivered from its irons, and returned to its source; it recognises itself to be a daughter of heaven from the delight it takes in celestial things; it enters there not as a stranger, but as if at home. An eager spectator, there is nothing but it sounds and interrogates. Ah! who could hinder it? Does it not know that all this is its domain? Man does not live on bread alone—he requires thought. It is on rising to these noble contemplations that he becomes worthy of his rank; it is by occupying his mind with these beautiful and fertile subjects of study that his countenance will preserve the divine expression of his destiny, and will shine more and more. Let us not forget the teachings of the night, but return sometimes to meditate under its silent gloom. Instead of a passing reverie, now that we have partly lifted the veil which hid the celestial mysteries from us, our minds will have an object better understood; we shall understand what we admire, and we shall better appreciate these distant creations. These nocturnal hours will have a double value in our eyes, as they will place us henceforth in communication with worlds whose natures are no longer unknown to us. And it is with greater intimacy that we shall address that salutation to the Night, with which we opened our interview with the heavens :—

> ‘ O Nuit ! que ton langage est sublime pour moi,
> Lorsque seul et pensif, aussi calme que toi,
> Contemplant les soleils dont ta robe est parée,
> J’erre et médite en paix sous ton ombre sacrée ! ’

THE END.

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